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AGRONOMY JOURNAL

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Effect of Selecting within Selfed Lines on the Yield and Other Characters of Cotton[1]

D. M. Simpson and E. N. Duncan[2]

TRADITIONAL methods of breeding cotton have been based largely on individual plant selection and plant-to-row-to-field increase of desirable progenies. Such selections have been made within populations already heterozygous or made so by controlled hybridization. Most of the widely grown cotton varieties in the United States have been developed and maintained by individual plant selections within open pollinated populations. Natural cross pollination occurs frequently in cotton, thus, these varieties contain much genetic variability even after many years of development and commercial use. In some breeding projects, emphasis has been placed on selections within self pollinated lines in development and maintenance programs and at least two important commercial varieties (1) (5)[3] are being maintained by selfed line methods.

A common objection to maintenance by selection within selfed lines has been that line breeding narrows the adaptiveness of a variety or strain to a particular locale or environment and, it is reasoned, such cottons perform poorly if subjected to ecological conditions different from those under which the breeding has been done. Some observations have indicated decline in vigor and productivity with prolonged line breeding. Leake and Prasad (9) working with cottons of the Asiatic type obtained evidence that a considerable degree of pollen sterility resulted from self-fertilization repeated through a number of successive generations and concluded that by self-fertilization, some danger is incurred of the loss of vigor and even loss of the race through sterility. Kearney (7), however, found no evidence of deterioration in Pima cotton by selfed line breeding during seven successive generations and assumed that in Pima cotton factors contributing to low fertility had been eliminated during the development of the variety. Brown (2) tested inbred against crossed seed of eight varieties of upland cotton at Baton Rouge, La. He found that the massed inbreds (without selection) produced 9.3% less seed cotton, had 6.2% fewer blooms, and the bolls were 9.3% less in weight than comparative growths from seed maintained by mass intravarietal crossing.

Harland (4), by selection for a specific property (lint index), demonstrated that improvement could be obtained in sea island strains that previously had been self-fertilized for 15 generations. Little experimental data have been presented, however, to show whether or not selfed lines may be maintained indefinitely by judicious selection at a high level of over-all excellence or continuously improved. Data on this subject obtained in studies of cotton grown at the U. S. Cotton Field Station at Knoxville, Tenn., are given here.

MATERIALS AND METHODS

The planting material used was developed in breeding investigations begun in 1936 and continued until 1945. An original collection of 235 seed lots, representing practically all of the American upland varieties being grown at that time, was made by Dr. O. A. Pope for the inauguration of a selfed-line breeding project. One hundred and fifty-five additional strains were added to the collection in 1937 and 1938. From the beginning all progenies selected for continuation were propagated from selfed seed. During the first two years, particular attention was paid to individual plants within the progeny rows and selection of superior individuals was made on the basis of performance as judged by the breeder from field notes and laboratory data. With less type segregation in the later years, plants were selected for continuation more and more as representative of superior progeny rows rather than on individual plant performance. Although progenies that had the best combinations of desirable properties were selected for continuation, lint length was always of primary importance and was under constant selection pressure for improvement. Fiber strength was first measured on the 1942 crop and was considered in making selections each year thereafter. Any changes in fiber strength between 1936 and 1942 would be largely fortuitous.

As the breeding project progressed, sibs and remnants of the lines continued in each season were held in storage in the seed files. Thus, seed propagated by continuous self pollination for 1 to 10 generations was available from a large number of selfed lines. From these reserve seed stocks a selfed strain was chosen from each of four varieties to test the effect of prolonged selfing and selection on yield and other properties. The four varieties; Delpress 3, Stoneville 5, Delfos 719, and Coker 33–12 were chosen because they were considered to be the best lines still retained after 10 years of selfing and selection. The tests were limited to the 1st, 4th, 7th, and 10th selfed generations of the four strains.

As the reserve seed stocks were too small to plant a well replicated test and varied in age from 1 to 10 years, the seed from the sibs and remnants for each generation to be tested was bulked and an increase plot of each seed lot was grown in 1946. Massed selfed seed was obtained from these increase plots for a randomized test planting. The seed, thus, had one generation of mass selfing beyond the year designated for the seed lot.

The difference between generations or "years" within variety was considered of most importance in this study and the field planting was designed to provide as much precise information as

[1] Contribution from Division of Cotton and Other Fiber Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Dept. of Agriculture, and the Tennessee Agricultural Experiment Station, Knoxville, Tennessee, cooperating. Received for publication April 21, 1952.

[2] Agronomist and Bio. Science Aid, respectively.

[3] Figures in parenthesis refer to "Literature Cited".

Table 1.—Mean values for yield, length, lint percent, strength, lint index, and weight per 100 seed of 4 seed lots of each of 4 varieties of cotton. The seed lots represent selected pedigreed lines after 1, 4, 7, and 10 years of selfing.

	Seed Lot (Year)	Delpress 3		Stoneville 5		Delfos 719		Coker 33–12		Combined Mean
		Mean	S.D.*	Mean	S.D.*	Mean	S.D.*	Mean	S.D.*	
Yield (Gms)	1936	78.3	31.6	104.3	33.9	110.9	39.0	80.1	28.6	93.4
	1939	71.0	31.7	72.6	31.4	94.0	36.5	77.1	33.3	78.7
	1942	56.3	29.3	72.5	36.3	65.1	27.2	73.7	30.4	66.9
	1945	67.8	32.4	83.7	40.0	95.0	38.5	71.3	32.2	79.4
LSD (.05)		9.0		9.9		12.2		——†		5.0
Length (Inches)	1936	1.044	0.055	0.992	0.114	1.091	0.047	1.097	0.044	1.056
	1939	1.058	.047	1.039	.040	1.182	.040	1.084	.050	1.091
	1942	1.063	.055	1.058	.040	1.163	.039	1.090	.045	1.094
	1945	1.072	.055	1.161	.076	1.169	.036	1.092	.051	1.124
LSD (.05)		0.014		0.023		0.013		——†		0.008
Lint percent	1936	36.8	1.0	40.7	1.7	38.2	1.0	39.0	1.5	38.7
	1939	38.5	1.1	40.2	1.4	37.8	1.1	40.0	1.0	39.1
	1942	38.4	1.3	40.0	1.4	38.6	1.0	39.4	1.2	39.1
	1945	38.3	1.0	38.2	2.6	38.8	1.0	39.3	1.3	38.6
LSD (.05)		0.3		0.5		0.3		0.3		0.2
Strength index	1936	8.13	0.50	6.56	0.38	7.55	0.44	6.92	0.39	7.29
	1939	7.85	.42	6.52	.32	7.41	.43	7.00	.32	7.19
	1942	7.95	.41	6.54	.31	7.32	.40	7.04	.33	7.21
	1945	7.88	.41	6.93	.49	7.22	.41	6.94	.41	7.24
LSD (.05)		0.12		0.10		0.14		——†		0.06
Lint index	1936	5.97	0.87	6.90	0.74	7.22	0.66	6.33	0.95	6.61
	1939	6.34	.87	6.63	.81	6.30	.74	6.38	.89	6.41
	1942	6.12	.80	6.60	.85	6.29	.77	6.19	.83	6.30
	1945	6.17	.89	6.78	1.14	6.85	.81	6.13	.95	6.48
LSD (.05)		0.22		0.24		0.22		——†		0.11
Weight per 100 seeds (Gms)	1936	10.26	1.30	10.04	0.96	11.68	1.10	9.89	1.24	10.47
	1939	10.12	1.06	9.82	.97	10.36	1.12	9.57	1.27	9.97
	1942	9.92	1.01	9.89	1.00	10.02	1.20	9.49	1.19	9.83
	1945	9.92	1.26	10.95	1.52	10.78	1.14	9.46	1.08	10.28
LSD (.05)		0.31		0.32		0.35		——†		0.16

* Standard deviation for the distribution of individual values.
† "F" values indicate no significance.

possible on that phase. For each variety 100 replications consisting of four plants (one plant of each of the four test generations) were planted in randomized blocks. The plants were evenly spaced 24 inches apart in 42-inch rows. Data from replicates that had an imperfect stand were not used in the calculations nor were data from replicates that were adjacent to a missing hill. The number of replicates actually used in the calculations of means and variances were 89 for Delpress 3, 94 for Stoneville 5, 70 for Delfos 719, and 85 for Coker 33–12.

Samples for laboratory analysis were ginned on a roller gin and all laboratory data were derived from these samples. Lint lengths were determined by duplicate fibrograph measurements of lint samples from each plant. Four strength determinations were made on each sample with the Pressley Strength-Tester. All field samples were harvested by plant and row number and all laboratory analyses were completed with the samples in the same sequence as they occurred in the field. In this way, the random order of "years" was maintained until the data were ready for compilation and any consistent operator or instrument differences during the period of analysis could not result in bias favoring any particular generation.

EXPERIMENTAL RESULTS

Mean values for yield, length, lint percent, strength, lint index, and weight per 100 seeds for the four seed lots of the varieties are given in table 1. In the selection of plants for propagation from self-line populations, plants are usually chosen on the basis of individual performance rather than upon the mean of a large population. The standard deviations, therefore, are given for the distribution of individual determinations in order to show the variability of the material after 1 to 10 generations of selfing. In the analysis of variance a breakdown of the degrees of freedom for generations ("years") was made to study linear, quadratic, and cubic trends. Also, the comparison of 1936 seed lots versus other years was made in the variance analyses.

It should be emphasized at this point that these data represent accurate evaluations of cumulative results in a selfed line breeding program that was continued for 10 years. Although selection pressure was applied each year for the improvement of such properties as yield, lint percent, and fiber length, progenies were selected for continuation on a basis of combined qualities. Thus, the intensity of selection pressure for specific properties varied from year-to-year in the endeavor to select progenies with the best general combination of qualities. Consistency in behavior of different varieties would not necessarily be expected under such conditions of selection. The results in

the intermediate years serve to point out the periods during which changes occurred, but the overall effect of the selfing program is in the comparison of 1936 versus 1945 seed lots.

In the data for Stoneville 5, consideration should be given to the possible cause of the marked difference between the data from the 1945 seed lot and those of other years. The progeny data on Stoneville 5 indicate that no unusual change occurred in that variety between 1936 and 1944. The abrupt change in fiber length and other properties was first noted in 1945. The progeny row in 1945 was the progeny of a single plant selected in 1944 and of a single seed produced in 1943. A change of this magnitude after eight years of selfing might result from a major mutation or from an accidental outcross. Since the changes in seed and fiber properties were accompanied by appreciable increases in the respective standard deviations, the outcross explanation is the more plausible. Although the 1945 Stoneville 5 is highly suspect of being an outcross, no positive proof exists. The data for this generation, therefore, have been included in the statistical analyses.

Data for Delpress 3, Stoneville 5, and Delfos 719 indicate that these varieties followed the same general pattern of behavior in respect to yield, characterized by a decline during the early generations of selfing and an upward trend from 1942 to 1945. The upward trend for yield during the later years could have been the result of shifting the basis of selection from individual plant performance to general performance of the progeny row, thus, using a more accurate measure of yield components. In all cases, however, the 1945 seed lots yielded significantly less than the 1936 seed lots, the decreases for the three varieties being 13%, 20%, and 14%, respectively. The data for yield of Coker 33–12 showed no significant difference between Years, but there was a definite trend for yield to decline as the number of generations of selfing increased.

When the yield data of all varieties were combined into one analysis, the differences for Year effects were highly significant. The general pattern of yield for the combined varieties corresponds closely to that of the individual varieties. Yields decreased markedly during the earlier years of selfing and increased somewhat during the later years. The comparison 1936 versus Other Years showed that the drop in yield from the high of 1936 was highly significant. Variety $\times$ Years effect was significant as expected from results obtained by analyzing the varieties separately.

Length was under constant selection pressure in this breeding program and, in general, this was the only property in which major improvement was obtained. Relatively large increases in length were obtained in Delpress 3, Stoneville 5, and Delfos 719, but there was no significant change in Coker 33–12. In Stoneville 5, the total gain of 0.169 inches in lint length was the largest made in any of the varieties under study. Much of the increase in length in this variety occurred between 1942 and 1945, a period in which the variety is suspect of being outcrossed.

There was no consistent pattern of behavior among the several varieties in respect to lint percent or fiber strength.

Lint index and seed weight were not given primary consideration in selection but these values evidently were affected by selection for associated properties or by continuous selfing or both. In Delpress 3, the increase in lint percent in the earlier years of selfing was associated with an increase in lint index and a decrease in seed weight. With further selfing there was a decline in both lint index and seed weight between 1939 and 1942 and only a minor change in lint index thereafter. In Stoneville 5, there were minor declines in lint index and seed weight during the earlier years of selfing. There were increases in both values, particularly in seed weight, between 1942 and 1945. In Delfos 719, lint index and seed weight decreased during the early years of selfing but there was some increase in these properties between 1942 and 1945. In Coker 33–12, there was no significant change in lint index during the 10-year period. There was a significant linear trend for seed weight to decrease with continued selfing and selection.

In the combined data, there was an immediate increase between 1936 and 1939 in the values for length and lint percent as might be expected from selections within heterozygous populations. As frequently occurs in cotton breeding, selection for high lint percent resulted in lower seed weight and lower lint index. Between 1939 and 1942 there was little change in any value other than yield, although minor declines in lint percent, lint index, and seed weight occurred. The data indicate significant changes in fiber strength but they were extremely small and of minor agronomic importance.

In the statistical analysis of the combined data for length, lint percent, strength, lint index, and seed weight, the "Year" effects were significant in terms of the general error term for the experiment. In each case, however, the interaction "Variety $\times$ Years" was highly significant indicating that, when examining the behavior of these characters in cotton varieties, the effect of "Years" should be studied within the individual varieties rather than from the pooled data.

The data from the 1945 seed lots for all varieties combined are so greatly influenced by the abrupt change in the Stoneville 5 variety that minor changes in other varieties is completely over-shadowed. Since the evidence indicates that the 1945 seed lot of Stoneville 5, possibly, is a recent accidental outcross, generalizations of results from the 1945 seed lot data are unwarranted.

DISCUSSION

The four selfed line strains from which data have been presented were considered to be the best of those developed in this breeding study. The results, thus, represent the maximum progress attained in 10 years by selfed line breeding methods in an original collection of 390 seed lots. The experimental results indicate that in this program of selfing and selection there has been an average loss of 15% in yield and that this loss has not been fully compensated by gains in other properties. Thus, in all varieties the selected strains were of less commercial value at the end of the 10-year breeding period than at the beginning.

The failure to develop a superior strain of cotton by the methods used here may have been a matter of chance, or of poor judgment in selecting progenies for continuation of the lines. But on the other hand, the failure may well be due to limitations of the line breeding method for continuous improvement and maintenance. As stated by East and Jones (3), inbreeding is not necessarily injurious unless undesirable characters preexist in the stock prior to inbreeding. However, if desirable behavior in an open-pollinated population is in part the result of heterosis, then loss can occur with inbreeding by bringing into expression undesir-

able recessive genes previously masked by favorable dominant genes.

It has been shown by Kime and Tilley (8), and others (12) (6), that appreciable increases in yield may result from heterosis in intervarietal hybrids of upland cotton. Reduction in hybrid vigor through successive generations of selfing is of the order ½, ¾, ⅞, etc., in hybrids between homozygous lines. A similar reduction in hybrid vigor would logically be expected when any heterozygous line is selfed. In any population, theoretically, the number of heterozygous gene pairs will be reduced by ½ at each successive selfed generation.

The normally expected regression in yield of a hybrid or heterozygous line when selfed, might be offset by the selection and continuation of the more productive individual plants. It has been suggested that these more productive individuals are the most heterozygous and, therefore, the selection practiced tends to perpetuate this heterozygosity.

Proponents of line breeding as a means of varietal maintenance have stressed the effectiveness of selfing in obtaining uniformity of plant and fiber characters. Lack of uniformity may be due to either genetic or environmental causes. In the present study, the data indicate that, with the possible exception of Stoneville 5, reasonable stability had been attained in four selfed generations. In all varieties and for all characters studied, however, the plant-to-plant variations as indicated by the standard deviations remained relatively large after 10 selfed generations. The wide differences in the measured properties of individual plants made it possible to select seemingly desirable plants after each successive generation of selfing. These selections, however, were made on the basis of gross variations which after 1939 were largely environmental. Once major genetic variability has been removed, line breeding affords meager opportunity for improvement and may result in actual deterioration in variety value if continued beyond the minimum requirements for stability.

Selfing is a useful tool in the isolation and stabilization of specific characters such as disease resistance, particular fiber properties, or other desirable plant characteristics but selfing *per se* cannot be considered a logical method for improvement or even maintenance of an agronomic variety. As pointed out by Richmond and Lewis (11), a broad adaptation base is desirable in commercial cotton varieties and may be provided by maintaining a certain amount of heterozygosity. Selfing with selection can play an important part in isolating desirable biotypes, but for preserving a broad adaptation there is need for recombining biotypes that are similar in major agronomic characteristics but which may differ genetically in their environmental responses.

No one has demonstrated that extreme uniformity is needed or even desirable in the so-called "bread-and-butter" cottons. Certainly, loss in yield cannot be justified unless uniformity can be translated into terms of better spinning and higher value per pound of fiber. Rigid adherence to fixed standards of plant type, leaf shape, boll size and shape, and other plant characters can needlessly handicap a cotton improvement program unless these characters are directly indicative of economically important properties. Likewise, new strains selected from hybrids and synthetic varieties may be unnecessarily withheld from commercial production during the early and possibly their most productive generations by undue insistence upon uniformity of plant and fiber properties. Richmond and Lewis (11) found that lint from some varietal mixtures gave significantly higher levels of fiber strength than was expected from the calculation of the weighted mean fiber strength of the component varieties. O'Kelly (10) found the spinning efficiency of a variety was affected very little by the addition of a small percentage of lint of a variety with widely different fiber properties and still less or none when the fiber of the two varieties did not differ much. More information is needed on the spinning qualities of cotton from field mixes or blends of fiber from strains or varieties with unlike properties. Such information may aid in the removal of artificial barriers that have discouraged the maximum use of hybrid vigor in cotton production.

SUMMARY

Populations of cotton selections representing the 1st, 4th, 7th, and 10th selfed generations were interplanted in randomized experiments to study the effect of continuous selfing and selection on yield, lint length, lint percent, strength, lint index, and seed weight. The experiment included four varieties of cotton chosen as representative of the best lines retained after 10 years of selfing and selection from an original collection of 390 seed lots.

In spite of selection pressure to improve the desirable properties in these cottons, there was no marked gain in any property except lint length. Average values of the four varieties indicated a loss of 15% in yield of seed cotton and minor losses in lint percent, lint index, seed weight, and strength. The average gain of 0.07 inch in lint length was not sufficient to offset the loss in value due to decreased yields. In each variety the commercial value was less at the end of the 10-year period of selfing and selection than at the beginning.

It is suggested that the superior performance of the early generations is in part the result of heterosis and that loss occurred as homozygosity was approached. Present standards for uniformity in cotton varieties may impose artificial barriers that discourage the maximum use of hybrid vigor.

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Fertilizer Effects on Botanical and Chemical Composition of White Clover-Dallisgrass Associations Grown on Sumter Clay[1]

James M. Brown and R. D. Rouse[2]

THROUGH use of fertilizers and proper seeding, excellent white clover-Dallisgrass pastures can be established on Sumter clay in the Black Belt of Alabama. However, after a few years of production, the white clover population tends to disappear. In general, the persistence of clovers in mixtures with grasses is known to be influenced by many factors that can be classified as climatic, cultural and biological in nature. Information available on magnitude of the effect of specific factors in each category is insufficient to permit definite recommendations to be made.

Blaser and Brady (1)[3] have reported results indicating that nitrogen and potash fertilization definitely affected the botanical composition of Ladino clover and non-legume associations. They found that potassium stimulated the growth of Ladino clover, but it did not directly affect the productivity of the non-leguminous plants in the association. Nitrogen fertilizers increased the growth of grasses and decreased the growth of leguminous plants. As the growth of grasses was increased, the amount of potassium removed by the grasses was increased. Hence, the concurrent and/or after effect of nitrogen reducing the leguminous associate was attributed to competition for potassium.

In earlier studies Rich and Odland (6) reported that a reduction in potash fertilization lowered the proportion of legumes in grass-legume hay. However, Brown (2) reported that potash added to either superphosphate or superphosphate and limestone did not greatly affect the amount of white clover in a clover-grass sod.

Robinson and Sprague (7) found that high rates of nitrogen fertilization without irrigation greatly decreased the stand of clover in white clover-Kentucky bluegrass sod. On plots clipped to 2 inches the clover was practically eliminated, but with more severe clipping treatments, considerable amounts of clover were maintained even with heavy nitrogen fertilization. Other workers (2, 3, 4, 5 and 9) have shown that nitrogen fertilization reduced the clover in clover-grass associations.

This investigation was conducted to determine the relative effect of applications of potassium, nitrogen and certain minor elements on the maintenance of white clover grown in mixtures with Dallisgrass on Sumter clay. Chemical analyses were made on the plant material produced to study the relationship of the potassium and calcium content of plants grown on this calcareous soil to yield and plant nutrient level in the soil.

EXPERIMENTAL

The greenhouse investigation was initiated in December 1949 on Sumter clay from the Black Belt Substation, Marion Junction, Ala. This soil had a pH of 7.8 and contained about 50% free calcium carbonate and 62 ppm exchangeable potassium. The clay fraction of Sumter clay is montmorillonitic.

The treatments consisted of uniform phosphorus at the rate of 240 pounds P_2O_5 per acre and five rates of K_2O (0, 30, 60, 90 and 120 pounds per acre) with each of three rates of nitrogen, (0, 90 and 180 pounds per acre). Ammonium nitrate, superphosphate and muriate of potash were the sources of N, P and K, respectively. One-third of the nitrogen was applied at each of three application dates. These 15 treatments also included minor elements at the rate of 10 pounds borax, 10 pounds zinc sulfate, 10 pounds copper sulfate and 20 pounds manganese sulfate per acre. Applications of 0.05% ferrous sulfate solution were applied as a spray at frequent intervals to prevent chlorosis from iron deficiency. Rogers (8) had previously shown that application of ferrous sulfate to the soil did not correct iron deficiency of crimson clover on Sumter soil.

Three additional treatments included rates of nitrogen without minor elements. These treatments received standard rates of 90 pounds of K_2O and 240 pounds of P_2O_5 per acre. The fertilizer used in the initial application was thoroughly mixed with the 16.2 pounds of inoculated Sumter clay used in each of the 2-gallon glazed pots. The second annual application of fertilizer was applied as a top-dressing on September 26, 1950.

The experiment was designed as a randomized complete block with three replications. The stand established in each pot consisted of 11 Improved Louisiana White Clover, *Trifolium repens*, plants and 4 Dallisgrass, *Paspalum dilatatum*, plants. The two species were clipped individually to a height of about 1 inch at various intervals throughout the study. The entire clippings were dried in a forced draft oven for 48 hours at 70° C. Cumulative yields were then expressed on a basis of grams of dry matter per pot.

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[3] Figures in parenthesis refer to "Literature Cited."

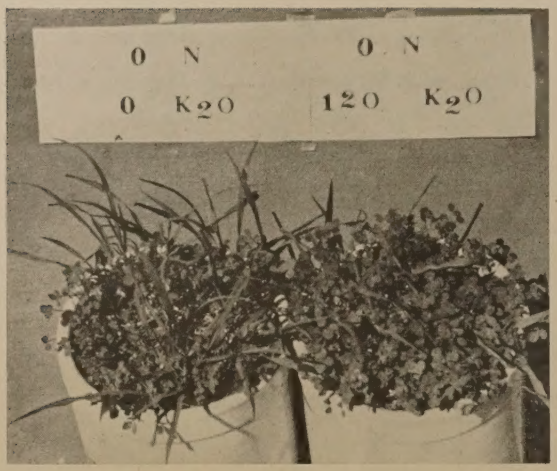

FIG. 1.—Increased white clover growth and the decreased Dallisgrass growth resulting from the addition of potassium.

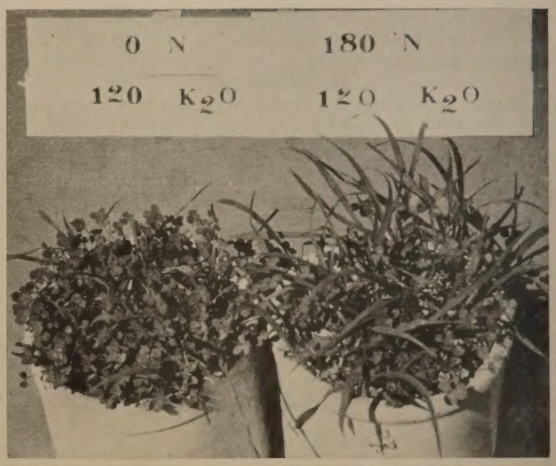

FIG. 2.—Increased Dallisgrass growth and decreased white clover growth resulting from the addition of nitrogen.

Individual clippings of both species from each pot were analyzed for potassium and calcium. The plant samples were dry ashed and analyzed for calcium by the micro permanganate method and for potassium by use of the internal standard procedure on the Perkin–Elmer Flame Photometer, model No. 52-A.

The effects of treatments on the cumulative yields were evaluated statistically by the method of analysis of variance and orthogonal comparisons.

RESULTS AND DISCUSSION

This experiment was conducted for 20 months during which seven clippings were obtained. It was necessary to discontinue the experiment at this point because of an infestation of soft brown scale which could not be effectively controlled. Clover was eliminated in several pots by scale between the sixth and seventh clippings; therefore, the seventh clipping was not used in the analysis of variance. Grass was not established before the first clipping hence there was one less clipping for grass than for clover. This explains their difference in degrees-of-freedom in the analysis of variance.

The effects of treatments on the accumulated yields of grass, clover and clover-grass herbage are shown in tables 1, 2 and 3 and figures 1 and 2.

As shown in the analysis of variance (table 2), nitrogen fertilization caused a distinct increase in yields of Dallisgrass and clover-grass herbage. This increase in total herbage was due to the grass alone since nitrogen had no significant effect on the accumulated clover yield. This is true for all levels of potash fertilization.

Further study of the data and analysis of variance shows that potash fertilization resulted in a highly significant increase in total white clover yields. There was no significant change in herbage yields even though the clover was increased by potash. This was true because the Dallisgrass yields were decreased. The decrease in grass yields from additional potash was highly significant. This decrease appeared to be caused by competition from invigorated clover as a result of potash fertilization.

The effect of time on treatments was evaluated by the examination of individual clippings. Since cumulative yields were used for this examination, there necessarily had to be an upward trend in yields if the plants made any amount of growth. Through this examination, it was disclosed that time effect was different with the various levels of nitrogen (table 3). The rate of cumulative yield increase of clover, grass and clover-grass herbage were all affected by nitrogen levels. In the case of white clover, nitrogen fertilization re-

Table 1.—Accumulated yields of white clover and Dallisgrass grown in combination on Sumter clay in the greenhouse.

Fertilizer Treatments Lbs/Acre*			Accumulated Forage Yields† Gms Per Pot		
N	K_2O	Minor‡ Elements	Dallisgrass	White Clover	Total (White Clover and Dallisgrass)
Lbs/A	Lbs/A	Lbs/A	Gms/Pot	Gms/Pot	Gms/Pot
	0.0	50	38.15	41.56	79.71
	30	50	31.51	54.11	85.62
0	60	50	36.37	49.45	85.82
	90	50	29.74	56.62	86.36
	120	50	21.65	58.77	80.42
	90	0.0	41.46	42.48	83.94
	0.0	50	62.91	42.78	105.69
	30	50	44.64	51.68	96.32
90	60	50	54.75	41.95	96.70
	90	50	38.27	59.10	97.37
	120	50	41.62	56.29	97.91
	90	0.0	50.51	29.89	80.40
	0.0	50	79.92	31.91	111.83
	30	50	66.77	42.83	109.60
180	60	50	66.22	44.72	110.94
	90	50	67.92	51.94	119.86
	120	50	58.46	52.85	111.31
	90	0.0	96.45	28.78	125.23

* All treatments received P_2O_5 at the rate of 240 pounds annually.

† Dried in a forced draft oven for 48 hours at 70° C.; average of 3 replications; includes 7 clippings.

‡ Consisted of 10 pounds of borax, 10 pounds copper sulfate, 10 pounds zinc sulfate and 20 pounds manganese sulfate, plus ferrous sulfate solution as a soray.

Table 2.—Analysis of variance of total white clover, total Dallisgrass and total herbage yields for clover-grass combinations on Sumter clay in the greenhouse.

Source of Variation	d. f.	Mean Squares		
		White Clover	Dallisgrass	Total Herbage
Treatments	17	228.384**	786.008**	464.550**
Minor Elements vs. none	1	2088.857**	1558.919**	144.954
Within the treatments receiving Minor Elements	14	145.473*	594.778**	338.491*
Linear effect of K_2O	1	1246.735**	1712.724**	6.370
Quadratic effect of K_2O	1	65.349	113.998	8.274
Linear effect of Nitrogen	1	16.842	5366.692**	3996.436**
Quadratic effect of Nitrogen	1	11.787	15.324	41.174
Linear effect of $K_2O \times N$ vs. none	1	35.909	3.329	18.668
Quadratic effect of $K_2O \times N$ vs. none	1	1.469	225.823	205.272
Error	34	69.807	125.783	166.616

* Significant.
** Highly significant.

sulted in a decrease in the rate which the cumulative yields were increasing. This trend indicates that had the experiment been conducted over a longer period of time there would have been a significant decrease in total clover yields. Nitrogen levels had the opposite effect on cumulative yield increase trends for grass and clover-grass herbage than for clover. There was no interaction of nitrogen and potassium on the linear effect of clippings.

The application of minor elements produced the same yield relationship as did the application of potassium. The yield of clover was larger, but the yield of grass was smaller from pots that received the minor elements. This inverse relation of clover and grass in response to minor elements resulted in the total herbage yields not being affected.

The last five of a total seven clippings were analyzed for calcium and potassium (table 4). The application of additional potash generally resulted in an increase in the potassium content of clover and grass. This was true at each nitrogen level. The application of nitrogen caused a decrease in potassium content of the grass but it did not cause a consistent change in potassium content of the clover. The minor element application resulted in reduced potassium content of both species.

The concentration of potassium in grass and clover does not show a true picture of the relative ability of each species in depleting the available soil potassium under different treatments. In an effort to determine if competition for potash was a determining factor in clover persistence, the parts-per-million potassium removed by each species was calculated (table 4).

In most cases the amount of potassium removed by grass was greater than the amount removed by clover. The level of K_2O fertilization had no consistent effect on the amount of potassium removed by grass. Additional increments of potash did increase the amount of potassium removed by clover; this was true at all levels of nitrogen fertilization. Increasing nitrogen levels were associated with a decrease in potassium removal by clover at the last two clippings.

Foliage symptoms that resembled potash deficiency were observed during this study. These symptoms appeared irrespective of treatment. This, plus the fact that in several cases more potassium was removed in the plant material than was added by fertilization, indicates that even the highest rates of potash were inadequate to prevent competition between clover and grass for potassium.

It has been reported by many investigators that there was an inverse relationship between the absorption of calcium and the absorption of potassium by plants. It seemed desirable to determine if this were true for plants grown on a soil that was very high in lime. Chemical analyses indicated that a decrease in calcium absorption was not associated with an increase in potassium absorption with one exception. The amount of calcium absorbed by grass decreased as the potassium content increased at the 180-pound level of nitrogen.

Table 3.—Analysis of clippings × treatment comparisons of cumulative white clover, Dallisgrass and herbage yields for clover-grass combinations in Sumter clay in the greenhouse.

Source of Variation	d. f.	Mean Squares		
		White clover	Dallisgrass†	Total Herbage
Clippings × Treatments	85	30.305**	86.386**	62.215**
Linear effect of clippings × N vs. none	1	32.803*	1863.304**	1991.590**
Linear effect of clippings × 90 lbs. N vs. 180 lbs. N	1	65.770**	632.085**	423.667**
Quadratic effect of clipping × N vs. none	1	1.832	1.734	38.509
Linear effect of clippings × N vs. none × K_2O vs. none	1	0.942	58.375	54.709
Error	180	6.648	21.999	21.383

† Degrees of freedom for error term of Dallisgrass is 144 instead of 180.
* Significant.
** Highly significant.

Table 4.—Calcium and potassium content and amounts of potassium removed by white clover and Dallisgrass grown in combination on Sumter clay in the greenhouse.

Fertilizer Treatments*			Potassium Content†		Calcium Content†		Potassium Removed‡	
N	K_2O	Minor Elements	White Clover	Dallisgrass	White Clover	Dallisgrass	White Clover	Dallisgrass
	Lbs/acre		%	%	%	%	p.p.m.	p.p.m.
0	0.0	50	0.52	0.90	3.32	1.16	23.3	42.9
	30	50	0.63	0.97	3.22	1.11	37.0	40.2
	60	50	0.72	1.06	3.38	1.06	37.4	48.7
	90	50	0.79	1.21	3.29	1.13	49.6	44.9
	120	50	0.87	1.33	3.39	1.05	58.1	38.0
	90	0.0	0.83	1.27	3.77	1.12	36.8	66.9
90	0.0	50	0.56	0.66	3.16	1.20	25.4	52.5
	30	50	0.61	0.75	3.24	1.25	35.4	44.9
	60	50	0.67	0.86	3.43	1.24	30.7	61.2
	90	50	0.75	0.99	3.36	1.15	50.8	51.1
	120	50	0.82	1.03	3.26	1.22	52.5	57.1
	90	0.0	1.00	1.12	4.26	1.30	27.2	71.8
180	0.0	50	0.48	0.50	3.47	1.46	16.9	49.0
	30	50	0.58	0.60	3.36	1.36	26.5	49.9
	60	50	0.64	0.72	3.43	1.28	31.8	57.3
	90	50	0.78	0.66	3.22	1.28	44.0	56.8
	120	50	0.83	0.84	3.41	1.18	48.8	60.2
	90	0.0	0.97	0.70	4.42	1.45	25.21	81.2

* All treatments received P_2O_5 at the rate of 240 pounds annually.
† Averages of 5 clippings.
‡ Total of 5 clippings.

There was no evidence in the data that would lead one to believe that the application of potash or nitrogen had any effect on the calcium content of white clover. The addition of minor elements, however, resulted in a consistent decrease in calcium content of clover. The addition of minor elements did not consistently alter the calcium content of grass. In every case the calcium content of white clover was two to three times higher than the calcium content of Dallisgrass. The grass seemed to increase in its ability to absorb calcium as the stand became older. The calcium content of clover was not altered by age of stand.

SUMMARY AND CONCLUSIONS

Through greenhouse and laboratory investigations, it was determined that the persistence of clover in white clover-Dallisgrass associations on Sumter clay is highly dependent on potash and minor elements fertilization. The following is presented as evidence that adequate potash and minor elements must be present in order to maintain a favorable clover content in mixtures.

1. The application of potash and minor elements resulted in an increase in clover and a decrease in grass content of the herbage.
2. Based on total potassium removed by five clippings, the grass removed more potassium in all cases than the clover except where no nitrogen was applied and the potash rates were 90 and 120 pounds per acre with minor elements.
3. Although potash fertilization increased the potassium content of both clover and grass, it did not appreciably affect the amount of potassium removed by grass.

Applications of nitrogen increased the total clover-grass herbage yields. This was a result of increased grass yields. The total yields of clover were not significantly affected. However, there was a significant decrease in clover yields associated with increasing rates of nitrogen as the stand became older.

The results of this experiment indicate that Dallisgrass has a greater ability than white clover to absorb potassium from the soil. This may be either a result of greater soil coverage by its fibrous root system or because it is able to absorb potassium from sources that are less available to clover. Thus, it is necessary to apply potash in excess of what is needed by the grass to provide an adequate supply for the clover.

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Production and Quality of Irrigated Pasture Mixtures as Influenced by Clipping Frequency[1]

Maurice L. Peterson and Robert M. Hagan[2]

THE management of grazing frequently has a greater influence upon the condition of a pasture than any of the factors of management. Unthrifty growth, weediness, or the presence of coarse unpalatable herbage often results from uncontrolled grazing. Grazing is being properly regulated by increasing numbers of farmers in California. By so doing, they are finding that yields are increased, selectivity in grazing is reduced, less forage is wasted, and the quality of the herbage when grazed is brought under some control.

Two somewhat different systems of controlled grazing are in use. Rotation grazing involves intensive grazing on an intermittent basis using heavy concentration of stock at each grazing period. Pastures are sub-divided into small units and the animals are rotated from pasture to pasture as each are grazed down in turn. With ration or strip grazing (called close-folding in British literature) the area grazed is restricted to the amount that can be grazed down in one day or in one feeding. The area is grazed at the rate of 50 to 85 animal units per acre and is enclosed with a portable electric fence moved daily.

An important question to be answered with either of these two systems of grazing is the length of growth intervals between grazings adequate to provide pasturage that is satisfactory in yields and quality, and is the length of such intervals also sufficient to maintain a proper balance between desirable species.

In preparation for controlled grazing studies now in progress, a clipping experiment was established at Davis in October, 1948, in which the intervals between cuttings were spaced at two, three, four, and five weeks. Four pasture mixtures were seeded, each differing in the legume part of the mixture while the grasses were the same and consisting of annual ryegrass 2 pounds, perennial ryegrass 2 pounds, orchardgrass 3 pounds, and alta fescue 4 pounds per acre. The legume portions of the four mixtures were as follows: Mixture 1, alfalfa 9 pounds per acre; Mixture 2, ladino clover 3 pounds per acre; Mixture 3, broadleaf trefoil 4 pounds per acre; Mixture 4, alfalfa 3 pounds, ladino clover 1 pound and broadleaf trefoil 1-1/3 pounds per acre. A split-plot design was used with the clipping treatments as the sub-units. Individual plots were 7 by 16 feet, with six replications.

The various clipping treatments were begun on April 1, in 1949 and on March 18 and 19 respectively in 1950 and 1951. The last cuttings of the season were made on approximately November 1. Almost complete absence of rain made it possible to adhere rigidly to the various clipping schedules throughout the three-year period. Plots were flood irrigated every seven days during the warmer part of the growing season and less frequently in the spring and fall.

[1] Contribution from the Department of Agronomy, University of California, Davis, California. Received for publication October 22, 1952.

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Yields were obtained by cutting a swath 3.5 feet wide the entire length of the plot at a height of approximately 2 inches. A moisture sample was taken on every plot at each harvest.

Samples of the fresh forage were taken for botanical analysis in July and September 1950. Determinations of the percentages of the different species was made on a moisture-free basis following hand separation. An additional sample was taken in July, 1950 for determination of crude protein, crude fiber, ash, ether extract, and nitrogen-free extract.

The number of cuttings per season and the average height of the green forage when cut were as follows:

Clipping frequency	Cuttings per season	Av. height, when cut
Weeks	Number	Inches
2	16	6.2– 7.6
3	11	9.4–12.4
4	8 or 9	11.2–19.6
5	7	10.4–25.7

The range in the height of the forage when cut may be attributed to the different mixtures, the shorter mixtures being those containing ladino clover or trefoil and the taller ones containing alfalfa.

Total Yields for the Season

Total yields for each season were adjusted to a 12% moisture content and are shown in table 1. The average yield for all four mixtures through the three years when cut every two weeks was 4.56 tons. Allowing three weeks between cuttings increased yields 23%, four weeks 50% and five weeks 92% or 8.77 tons per acre. Analysis of variance showed these differences were highly significant.

Of more interest than these averages are the responses of individual mixtures. Ladino clover with grass was the most productive of all mixtures cut at two week intervals. The alfalfa-grass mixture was the highest in production among the mixtures when cut at five-week intervals, but it was nearly the poorest when cut every two weeks. Extending the intervals of cutting from two to five weeks increased the yields of the ladino-grass mixture only 43% while the same extension with the alfalfa-grass mixture gave an increase in production of 177%. The trefoil-grass mixture and the mixture of alfalfa, ladino, trefoil and grass showed 90% and 86% yield increases, respectively, by lengthening the cutting intervals from two to five weeks.

The yields in 1950, the second year of production were greatest in nearly every treatment. Exceptions to this are alfalfa-grass mixtures which declined in yield from the first year when cut at two- or three-week intervals and broadleaf trefoil-grass mixtures which continued to increase in yield each season when harvested at four- or five-week intervals. It is a common observation that trefoil is slow starting, but improves as pastures become older.

Analysis of variance showed that differences in yields between mixtures and the interaction of mixtures × cutting treatments were highly significant. The interpretation of this interaction, as shown in figure 1; is largely the differential response to cutting treatment of the ladino-grass mixture and those mixtures containing alfalfa. The alfalfa-grass mixture was the highest in production among the mixtures when cut at five-week intervals, but nearly the poorest

Table 1.—Effect of cutting frequency upon the yields of four irrigated pasture mixtures grown in Davis from 1949 to 1951. (Yields in tons per acre at 12% moisture.)

Mixture	Frequency of cutting in weeks					
	Year	Two	Three	Four	Five	Average
Broadleaf trefoil with grass	1949	4.00	4.47	4.83	5.64	4.74
	1950	3.17	4.09	4.87	6.92	4.76
	1951	3.74	5.14	5.98	8.21	5.77
	Av.	3.64	4.57	5.23	6.92	5.09
Ladino clover with grass	1949	4.82	5.33	6.02	6.76	5.73
	1950	6.77	8.12	8.68	9.42	8.25
	1951	5.18	6.50	7.30	7.81	6.70
	Av.	5.59	6.65	7.33	8.00	6.89
Alfalfa with grass	1949	4.95	5.61	7.46	9.22	6.81
	1950	3.34	5.05	8.51	11.78	7.17
	1951	2.86	3.93	5.90	9.89	5.65
	Av.	3.72	4.86	7.29	10.30	6.54
Alfalfa, ladino, and trefoil grass	1949	4.71	5.17	6.68	8.26	6.20
	1950	5.74	6.98	8.60	11.56	8.22
	1951	5.43	6.71	7.31	9.66	7.28
	Av.	5.29	6.29	7.53	9.83	7.23
Averages for the four mixtures	1949	4.62	5.15	6.25	7.49	5.87
	1950	4.76	6.06	7.66	9.92	7.10
	1951	4.30	5.57	6.62	8.89	6.35
	Av.	4.56	5.59	6.84	8.77	6.19

when cut every two weeks. The ladino-grass mixture was best among the four mixtures when cut every two weeks, but was decidedly less productive than mixtures containing alfalfa when cut at five-week intervals. Ladino clover showed less yield response by extending the growth period from four weeks to five weeks than any of the mixtures.

Seasonal Distribution of Production

The distribution of production through the season is important in the management and utilization of pastures. Growth curves for the alfalfa-grass mixture are shown in figure 2. These curves are the averages of three years' results presented in terms of the daily yield of dry matter in pounds per acre. Maximum production was reached in late June under the five-week clipping schedule. This growth curve resembles the curve showing the hours of sunlight throughout the growing season. The peak of the production curve was reached in late June when the days were longest, almost reaching 100 pounds of dry matter per acre per day. Cuttings made at four-week intervals reduced yields sharply during May through August. With the more frequent cuttings, the advantage of the longer days was not fully utilized. The dip in production in mid-May when cuttings were made at four-week intervals occurred with all four of the mixtures and was extremely sharp during the 1950 and 1951 seasons. Information is not available to explain the cause of this depression. The time of its occurrence is believed to coincide with the period when the cool season grasses are just completing a vigorous growing period and the legumes are beginning to come into greater prominence in the sward.

The growth curves for the ladino-grass mixture (figure 3) shows a sharp contrast with the alfalfa-grass mixture. Maximum production was fully a month earlier and a sharp depression in growth occurred in late July and early August. It appears that temperature is a dominating factor and that the most favorable period for growth occurred during the cooler month of May with a sharp depression in growth during the hotter months of July and August. Maximum yielding capacity of ladino-grass mixtures was about 25% less than alfalfa-grass mixtures.

Growth curves for trefoil-grass mixtures showed maximum production in late June under five-week cutting frequencies. There was also some indication of a high temperature depression in late July although this trend was less striking than was the case with ladino clover.

The mixture containing alfalfa, ladino, trefoil and grass showed a growth curve very similar to ladino-grass when both were cut every two weeks. As will be shown later, the mixture was predominantly alfalfa when cut infrequently and predominantly ladino clover when cut frequently. In neither cutting treatment, however, were the yields as high as the simpler mixtures.

In figure 4, the growth curves of all four of the pasture mixtures are shown under the five-week clipping intervals. The apparent high temperature depression in growth of the ladino- and trefoil-grass mixtures is clearly evident. Also evident is the superior productive capacity of the mixtures containing alfalfa.

Botanical Composition

The effect of cutting frequency upon botanical composition of the various mixtures was determined by hand separation in July and September, 1950. As shown in table 2, the percentage of grass present in September was approximately double the amount present in July. This is not surprising in view of the cool-season growth characteristics of tall fescue, orchardgrass and the ryegrasses. It is apparent that in all the mixtures, the grasses decreased and the legumes increased as cuttings were spaced at wider intervals. Under the clipping treatments used, the legumes predominated all of the mixtures. The proportion of grasses to legumes did not differ greatly for the different mixtures, although the five-week cutting treatment tended to suppress the grass more when alfalfa was present than with the

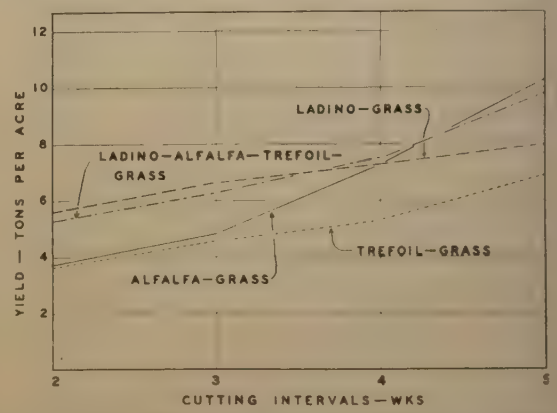

FIG. 1.—Average yields over a three-year period of four irrigated pasture mixtures as influenced by the frequency of cutting.

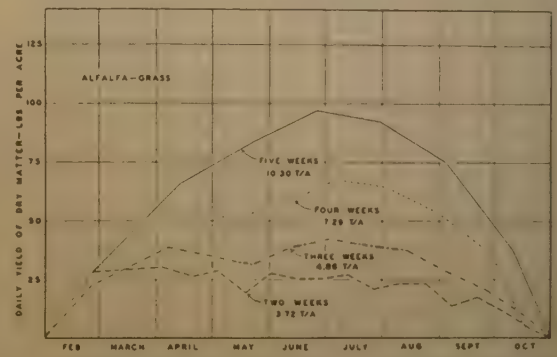

FIG. 2.—Average seasonal growth curves for an alfalfa-grass mixture harvested at intervals of two, three, four, and five weeks from 1949 to 1951 inclusive.

other two legumes. Alfalfa makes a more rapid and erect growth after clipping than ladino or trefoil and may therefore be more competitive.

The competitive relationships which existed between alfalfa and ladino clover when used in the same mixture are clearly shown in figure 5. With frequent cutting, ladino clover comprised 72.8% of the mixture with alfalfa making only 6.1%. At three-week cutting intervals, the spread was narrowed slightly, but when the intervals were spaced at four weeks, the alfalfa jumped to 67% and ladino clover dropped to 23.7%. At the five-week intervals between cuttings alfalfa comprised 94.2% of the mixture and ladino clover was practically eliminated. The broadleaf trefoil was apparently unable to compete with these two legumes, regardless of the cutting frequency.

Chemical Composition

The chemical composition of the different legume-grass mixtures is shown in table 3 from samples obtained in July, 1950. Samples were not analyzed throughout the experiment, but the figures show the influence of cutting treat-

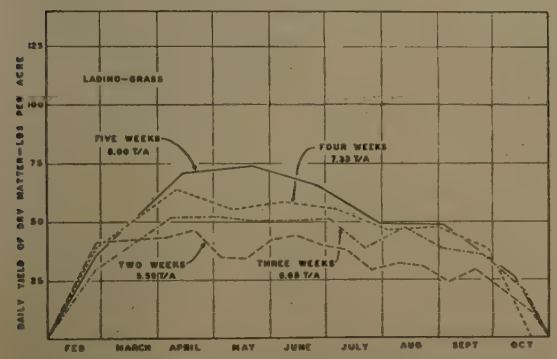

FIG. 3.—Average seasonal growth curves for a ladino clover-grass mixture harvested at intervals of two, three, four, and five weeks from 1949 to 1951 inclusive.

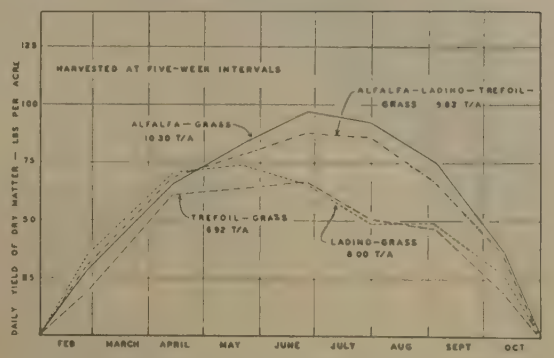

FIG. 4.—Average seasonal growth curves for four different irrigated pasture mixtures when each were harvested at intervals of five weeks over the three-year period, 1949–1951.

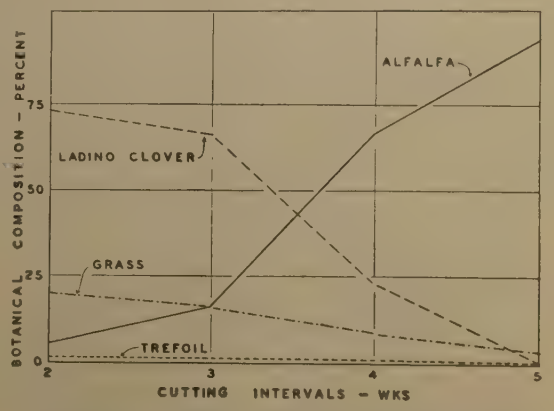

FIG. 5.—Effect of cutting frequency upon the botanical composition of an irrigated pasture mixture containing ladino clover, broadleaf trefoil, alfalfa and grasses, as determined by hand separations made in July, 1950.

Table 2.—Effect of cutting frequency upon the botanical composition of four irrigated pasture mixtures as determined by hand separations made in July and September, 1950. (Percentages on a dry-weight basis.)

Mixture	Component of mixture	Frequency of cutting in weeks							
		Two	Three	Four	Five	Two	Three	Four	Five
		%	%	%	%	%	%	%	%
		July, 1950				September, 1950			
Broadleaf trefoil with grass	Trefoil	77.0	87.8	91.5	91.2	46.8	58.1	75.1	81.0
	Grass	22.7	10.5	7.7	8.8	50.0	38.6	23.5	19.0
	Misc.	0.3	1.7	0.8	0.0	3.2	3.3	1.4	0.0
Ladino clover with grass	Ladino	79.9	84.7	87.8	90.0	56.5	69.6	77.6	79.1
	Grass	20.1	15.3	11.4	10.0	43.5	29.8	22.0	20.5
	Misc.	0.0	0.0	0.8	0.0	0.0	0.6	0.4	0.4
Alfalfa with grass	Alfalfa	71.7	88.2	93.7	96.5	44.1	65.6	87.7	95.7
	Grass	27.9	11.8	6.3	3.5	52.4	34.2	12.2	4.3
	Misc.	0.4	0.0	0.0	0.0	3.5	0.2	0.1	0.0
Alfalfa, ladino, and trefoil with grass	Alfalfa	6.1	15.9	67.0	94.2	1.1	8.3	70.5	87.4
	Ladino	72.8	66.7	23.7	1.8	58.1	57.4	14.4	4.0
	Trefoil	1.3	1.0	0.1	0.0	0.8	0.7	0.2	0.5
	Grass	19.8	16.4	9.2	4.0	40.0	33.6	14.9	8.1

ment and mixture upon the ash, crude proteins, ether extract, crude fiber and nitrogen-free extract at the time they were taken.

The ash content of all mixtures decreased as cuttings were spaced at wider intervals. Ladino clover-grass mixtures were least affected by cutting practices, there being only a small difference between the lowest and highest percentages of ash. Crude protein also diminished as cuttings were made less frequently, the range being quite large with the alfalfa-grass and ladino-grass mixtures. The alfalfa-grass mixtures were highest in crude protein and trefoil-grass mixtures were lowest.

The shift in botanical composition of the mixture containing all of the legumes brought about by cutting treatment was clearly reflected in the crude-protein determinations. As shown in figure 6 the crude protein for this complex mixture closely followed the ladino-grass mixture for the two- and three-week intervals between cuttings. Ladino clover comprised 72.8 and 66.7% of the mixture respectively for these cutting treatments. At the four- and five-week intervals between cuttings the percentage of alfalfa was 67.0 and 94.2% respectively and the crude protein percentage closely followed the alfalfa-grass mixture.

Ether extract tended to decrease as cuttings were spaced more widely, but the total amount present was small and the differences also were small. The crude fiber content increased sharply as the forage was permitted to become older. Mixtures containing alfalfa increased in crude fiber most rapidly with age while ladino clover increased least. The nitrogen-free extract showed no definite trends with cutting treatments. However, the mixtures containing alfalfa were somewhat lower in this fraction than the other mixtures.

DISCUSSION

Recently published experiments in England by Hughes and Redford (3) and Procter *et al.* (5), in Scotland by Holmes *et al.* (2), in the Netherlands by de Geus (1) and in New Zealand by Levy and Sears (4) have shown that the production from good pastures can be materially improved by intensive grazing on an intermittent basis using large concentration of animals on small areas which can be grazed down in a single day or a single feeding. de Geus (1) showed an increase of 24% in yield of starch equivalent using the daily ration system compared with rotation grazing. The number of farms using this system in Holland went from 2 in 1946 to around 5,000 in 1949. In Scotland, Holmes *et al.* (2) obtained milk yields of 550 gallons per acre for an orchardgrass-white clover pacture and 582 gallons per acre from a permanent pasture grazed on the daily rationed basis compared with 450 and 351 gallons respectively for the same pastures grazed rotationally. Hughes and Redford (3) used beef cattle in England to compare rotation with daily-rationed grazing, using the same stocking rates on each, but measured production differences by the amount of surplus feed which could be conserved for winter feed. In 1950, the dry-matter surplus under the daily rationed system was 13,017 pounds on two acres compared with 4,326 pounds under rotational grazing. Procter *et al.* (5) found an increase of 33% in grazing days per acre and an increase of 26% in pounds of milk produced per acre using daily rationed grazing compared with rotation grazing in England.

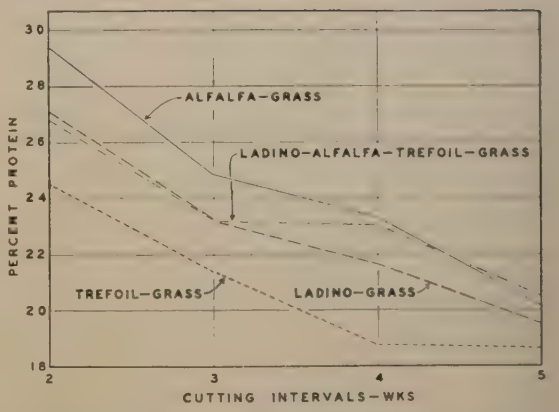

FIG. 6.—Effect of cutting frequency on the protein percentage of four irrigated pasture mixtures as determined by samples taken in July, 1950.

Table 3.—Effect of frequency of harvesting upon the chemical composition of different legume-grass mixtures sampled at Davis in July, 1950 (%-dry weight basis).

Mixture	Cutting frequency	Ash	Crude protein	Ether extract	Crude fiber	N-free extract
Trefoil-grass	2 weeks	12.1	24.6	2.4	15.7	45.2
	3 weeks	10.5	21.4	2.9	19.6	45.6
	4 weeks	10.5	18.8	2.4	23.5	44.8
	5 weeks	9.8	18.6	2.6	24.4	44.6
	Average	10.7	20.8	2.6	20.8	45.0
Ladino clover-grass	2 weeks	12.0	27.0	2.7	15.3	43.0
	3 weeks	10.8	23.3	2.6	16.9	46.4
	4 weeks	11.4	21.7	2.2	18.6	46.1
	5 weeks	11.7	19.6	2.2	21.1	45.4
	Average	11.5	22.9	2.4	18.0	45.2
Alfalfa-grass	2 weeks	12.0	29.4	2.3	15.5	40.8
	3 weeks	11.0	24.8	2.9	20.7	40.6
	4 weeks	10.7	23.3	2.0	25.3	38.7
	5 weeks	9.4	20.2	2.1	28.2	40.1
	Average	10.8	24.4	2.3	22.4	40.0
Legume mixture-grass	2 weeks	12.9	26.8	2.4	15.6	42.3
	3 weeks	11.1	23.2	2.8	18.0	44.9
	4 weeks	9.7	23.1	2.1	23.4	41.7
	5 weeks	9.8	20.5	1.8	28.6	39.3
	Average	10.9	23.4	2.3	21.4	42.0

The aforementioned increases in production from intensive grazing on an intermittent basis in the British Isles, Holland and New Zealand are explained on the basis of (1) greater yields, (2) less waste and (3) consumption of the herbage at a time when it had not become too mature to be both palatable and nutritious. The clipping studies reported have provided a good basis for establishing controlled grazing studies under irrigated conditions in California.

Total seasonal yields have continued to increase as intervals between cutting were extended to five weeks. Although it would have been desirable to have learned at what point yields might decrease by lengthening cutting intervals, this fact is of little importance to the problem since intervals of even five weeks were probably longer than desirable when consideration is given to the loss in quality and the anticipated waste from grazing overly

mature forage. Tesar and Ahlgren (7) have shown that under Wisconsin conditions, higher yields were obtained by making four cuttings per season compared with either two or six. Sprague and Garber (6) found that the time of removal of the first spring growth and the height of cutting both were important factors in maintaining the legumes in the mixture. They recommended removal of the first growth when it was 8 to 10 inches high and the subsequent growth when it was 8 inches high.

The seasonal growth curves have shown that good summer production is possible when available water is eliminated as a factor of production. Only in the case of the ladino clover and broadleaf trefoil mixtures was a depression in growth observed in the summer, but the amount of reduction was not great. It appears that the dominant factor in providing the growth rate peak in late June with alfalfa-grass mixtures is the amount of available sunlight.

On the basis of these studies and field observations, it appears that from 25 to 28 days should elapse between grazings of mixtures containing ladino clover as the primary legume in irrigated pasture mixtures. Pastures containing broadleaf trefoil or alfalfa should have slightly longer growth intervals, possibly 30 days, because of the sharp increases in production obtained by so doing.

If the pastures are to be grazed in rotation rather than by daily rationing of the pasture, these time intervals are probably too long because a tall growth when grazed down too slowly usually results in considerable wastage.

SUMMARY

Four irrigated pasture mixtures were harvested at intervals of two, three, four, and five weeks over a three-year period. Results were measured in terms of total seasonal yield, seasonal growth curves, botanical composition and chemical composition.

All mixtures increased in yields as growth intervals were extended from two weeks to five weeks. The average increase of all mixtures was 92%. Ladino clover-grass mixtures showed the least percentage increase (43%) and alfalfa-grass mixtures showed the most (177%) by lengthening cutting intervals.

Seasonal growth curves of mixtures containing alfalfa appeared to be related to hours of sunshine during the growing season. Mixtures containing ladino clover and broadleaf birdsfoot trefoil showed a slight depression in growth during late July and early August which coincided with the period of maximum summer temperatures.

The proportion of legumes increased and grasses decreased as cutting intervals were spaced more widely. The proportion of grasses approximately doubled from clippings made in July to clippings made in September. The cooler weather in September favored the growth of the grasses.

Chemical composition of the various mixtures and cutting treatments showed that ash, crude protein, and ether extract decreased in percentage with wider intervals between cuttings while crude fiber increased. Nitrogen-free extract was not greatly influenced by cutting treatments.

It would appear from the clipping studies as reported that grazing intensively at intervals of 25 to 28 days might be suitable for mixtures containing ladino clover as the primary legume but with trefoil or alfalfa as the dominant legume, a slightly longer interval between grazings should prevail.

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Soil Moisture Extraction by Irrigated Pasture Mixtures as Influenced by Clipping Frequency[1]

Robert M. Hagan and Maurice L. Peterson[2]

AMONG the more important factors which affect the production of pastures are soil fertility, species, grazing management, and the maintenance of favorable soil moisture conditions within the root zone. The influence of clipping frequency upon yield, botanical composition, and feed quality has been reported by Peterson and Hagan (6). Clipping (or grazing) at frequent intervals was found to greatly reduce the amount of herbage produced per acre. This factor might be expected also to influence root growth and thus the soil depth from which moisture could be extracted by the plant.

Numerous investigators have considered the effect of clipping on root growth in turf and forage crops, but few have investigated its effect on root depth distribution of mature stands under field conditions. Many of the clipping studies are reviewed by Salmon *et al.* (7), Graber *et al.* (4), and Biswell and Weaver (1). There is general agreement among the workers cited that the more frequent and severe the clipping treatment, the lower is the production of shoots, rhizomes, and roots. Similar conclusions have been reached in more recent work by Harrison and Hodgson (5), Carter and Law (2), and Wagner (10) from greenhouse investigations using young plants in containers and by Comstock and Law (3) from a field study. The latter workers compared root production by pure stands of alfalfa and by alfalfa-wheatgrass mixtures under two clipping schedules. Some plots were cut once per season for hay while others were cut two or three times which allowed recovery periods between clippings of approximately four weeks. The more frequently clipped plots produced a lower dry weight of roots with a higher percentage of roots in the top foot of soil and a lower percentage in the second foot.

An exception to the general conclusion that frequent clipping reduces depth of rooting appears in the report by Salmon *et al.* Alfalfa growing in the field was cut for nine years at four stages of growth which permitted average recovery periods of 31, 35, 40, and 51 days between clippings. The roots were washed out to a depth of 4 feet at the end of the second year. Large, healthy roots were found in all plots, but some dead and decaying roots were found under the most frequently cut treatments. When the roots were excavated at the end of the ninth year, a water table at 18 feet was found to have prevented further downward growth. Roots were seen at this depth in all cases and were assumed, on the basis of their size (1 to 2 mm. in diameter), to have been capable of penetrating further had soil conditions been favorable. No differences related to plot treatment were observed.

[1] Contribution from the Departments of Irrigation and Agronomy, University of California, Davis, Calif. Received for publication Jan. 6, 1953.

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It was the purpose of this investigation to determine the long-term effect of clipping frequency on moisture extraction and depth of rooting under mature stands of typical irrigated pasture mixtures.

MATERIALS AND METHODS

The plots used for the clipping experiment reported by Peterson and Hagan were utilized in this study. Three pasture mixtures were investigated, each containing a mixture of annual and perennial ryegrass, orchardgrass, and alta fescue but differing in the legume component. The legume portions consisted of ladino clover, broadleaf trefoil, and alfalfa each used alone. The plots were established in October, 1948, and for the next three years they were clipped at intervals of two, three, four, and five weeks during the growing seasons. Further details are given in the paper cited.

The almost complete absence of rain throughout the summer months made possible an accurate control of soil moisture conditions by irrigation. Plots were flood irrigated approximately every seven days during the warm part of the summer and less frequently in spring and fall.

The plots were located on a deep alluvial soil of the Yolo series. The texture varies with depth because of stratification. The surface soil and the soil to a depth of 8 feet are quite uniformly a loam or sandy loam. Below 8 feet, a clay stratum retards drainage and restricts the root development of deep-rooted plants such as alfalfa. Slow drainage through the clay layer made it impossible to evaluate accurately root activity in the lower portion of the profile during the first three weeks after irrigation. Aside from this difficulty, the soil was ideally suited to a detailed study of moisture extraction. The apparent (bulk) specific gravity of the soil, as determined using a standard California soil tube, varied little with depth, but in 112 measurements individual values ranged from 1.59 to 1.11. The mean of 1.36 was used for all depths in calculating consumptive use.

The effect of clipping treatments on rooting was studied by periodic soil moisture determinations continued until the plants were badly wilted. The relative activity of roots at any depth can be inferred from the rate of soil moisture extraction. No attempt was made to wash out and weigh the root systems since the weight of roots is not a reliable measure of their ability to supply water to the plant.

Soil moisture records were obtained in the third year during the months of July, August, and the first half of September for each of the mixtures at the four clipping intervals. After the winter, clipping was resumed on March 19, 1951, and terminated approximately two weeks before beginning soil moisture sampling. Three replications of each mixture were studied.

EXPERIMENTAL RESULTS AND DISCUSSION

Influence of Clipping Frequency

Soil-moisture extraction records at various depths for one replication of the ladino clover-grass series clipped at two, four, and five week periods are given in figure 1. The curve for the three-week period is very similar to the others. Although there are the usual minor irregularities in the extraction curves, they are quite smooth particularly in the upper portion of the profile. About 25 days after irrigation, the soil moisture content in the top two feet of soil approximated the average permanent wilting percentage (9.5%) indicating that most of the readily available water in this depth had been removed. Except for the continued slow

loss of moisture from the top half foot of soil caused by surface evaporation, very little further extraction occurred in the upper 2 feet of soil during the next five weeks. Below the third foot, drainage and lack of uniform wetting are largely responsible for the rapid changes and spread in soil moisture values during the first 20 days after irrigation.

Botanical counts during July indicated that the ladino clover fraction ranged from about 80% under two-week clipping to 90% under five-week clipping (see Peterson and Hagan). This difference in composition is small and permits one to evaluate the effect of clipping frequency on moisture extraction by a plant cover of nearly uniform population. It appears that clipping at intervals of two up to five weeks has not materially affected the soil-moisture extraction patterns. Most of the moisture absorbed has come from the top three feet, a little from the fourth foot, and very little from greater depths.

Clipping frequency had a greater effect on the botanical composition of mixtures containing trefoil and alfalfa. The percentage of trefoil in the grasses increased from 77 for the two-week period to 91 for the five-week period and that of alfalfa from 72 to 97 respectively. Despite these variations in composition, no distinct differences in moisture extraction could be detected within the trefoil or alfalfa series.

These findings suggest the following: Where repeated clippings at intervals of two up to five weeks produce little change in the botanical composition of a mature mixed-species pasture, such variations in clipping frequency should not require revision of the irrigation schedule. It is quite possible and even probable that cutting more frequently than two weeks or less frequently than five weeks may affect rooting depths.

Influence of Botanical Composition

There being no consistent differences in moisture extraction within each legume series under the four clipping schedules, the soil moisture data from one replication for each series have been averaged and plotted as figure 2 to facilitate comparison of mixtures. The legume component clearly influenced the moisture extraction pattern, although the grasses which are common to all mixtures accounted for as much as 28% of the plant material in some plots.

Considering first the top 2 feet of soil, the ladino clover plots extracted water the most rapidly and were the first to reach the permanent wilting percentage for each depth. After this, absorption at these depths nearly ceased. Trefoil mixtures were intermediate, and alfalfa mixtures the slowest. Plantings containing these two deeper rooted legumes did not reduce the moisture to the wilting percentages for the surface two feet of soil within the sampling period.

Within the third foot, differences in extraction rate between the clover and trefoil plots became small. In the fourth foot, extraction by trefoil plantings was faster and more complete than under the ladino. In the fifth foot, extraction by trefoil continued but had nearly ceased under ladino. In the sixth foot, extraction by trefoil and alfalfa continued at about the same rate. In the seventh foot, alfalfa showed active extraction, but in the eighth foot extraction was slow. No extraction records for the trefoil plantings were obtained below six feet.

From the above variations in soil moisture extraction, the relative distribution of absorbing roots can be inferred. In the ladino clover and grass mixtures, there are few absorbing roots below the fourth foot. However, in the trefoil-grass and alfalfa-grass mixtures, there apparently are considerable roots below this depth. A more graphic picture of water absorption and hence of root distribution can be obtained from figure 3 which is discussed below in connection with consumptive use rates.

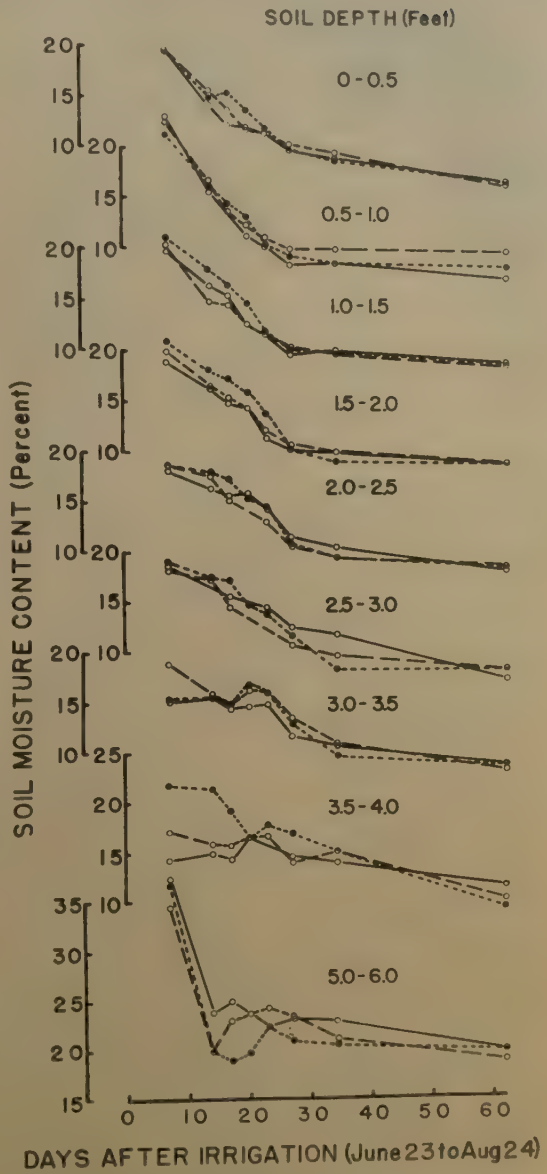

FIG. 1.—Soil moisture extraction by ladino clover-grass mixtures as affected by clipping frequency. Two-week intervals, solid line; 4-week, dashed line; and 5-week, dotted line.

For a given soil and climate, the frequency with which irrigation will be required depends directly upon the effective depth of rooting. The irrigation interval in a mixed

species pasture must be so regulated as to provide a continuous supply of readily available moisture within the effective root zone of the shallowest rooted component to be maintained in the pasture. More frequent irrigation may be required in soils where much of the fertility is restricted to the surface portion of the profile and where the available moisture is depleted in this topsoil while moisture is still available in the deeper but infertile horizons. In such soils, use of nearly all the readily available moisture within the root zone may cause the plants to suffer from inadequate mineral nutrition.

CONSUMPTIVE USE

Consumptive use, sometimes called evapotranspiration, refers to the loss of soil moisture by evaporation from the surface soil and by absorption through plant roots for use within the plant or in transpiration from the leaves. Consumptive-use values are very important in irrigation calculations. They indicate the rate at which water is lost in growing a crop, and thus the quantity of water that must be supplied in a given time from water stored in the soil by rainfall or by irrigation. Consumptive use is calculated by multiplying the change in soil moisture content (dry weight basis) for each foot depth by the apparent specific gravity of the soil (bulk volume) which for the soil studied was taken as constant and equal to 1.36. Total use is the sum of water used from each depth. In analyzing soil-moisture extraction curves for consumptive-use calculations, care must be taken to avoid soil moisture changes caused by drainage. Large moisture content changes arising from drainage are seen in figures 1 and 2 for soil depths below four feet. When most of the readily available moisture has been used and wilting appears, consumptive-use rates decline (see figure 3). If this occurs, the latter part of the irrigation cycle must also be avoided in computing maximum use rates.

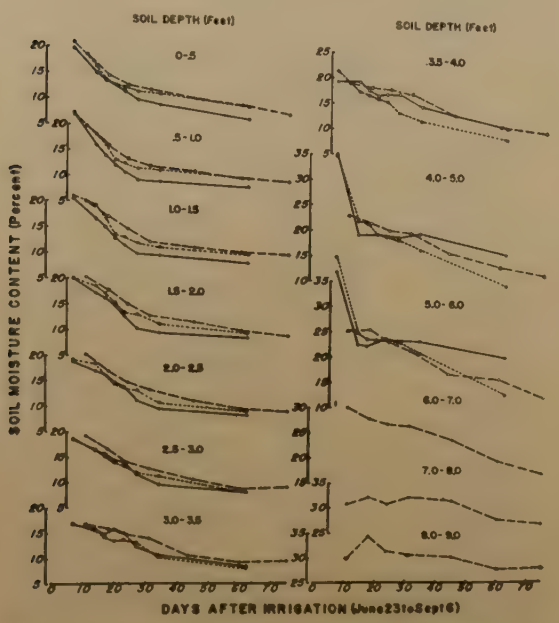

FIG. 2.—Soil moisture extraction by legume-grass mixtures. Points plotted are the average soil moisture contents from all clipping treatments for each mixture. Ladino clover and grass, solid line; alfalfa and grass, dashed line; and broadleaf trefoil and grass, dotted line.

Consumptive-use values for each legume-grass series by foot depths of soil and average total use rates from the entire soil profile, expressed in inches per day, are given in figure 3 for a number of weeks following the last irrigation. During the second and third weeks after irrigation, most of the water is extracted from the upper part of the profile. This is most striking in the ladino clover-grass mixtures. Differences in root distribution between mixtures are readily apparent. It is interesting to note that the zone of most rapid absorption shifts to greater depths with time particularly in the more deeply rooting trefoil and alfalfa mixtures. As time passes following irrigation, an increasing portion of the total water removed from the surface foot is lost from the top one-half foot indicating the effect of surface evaporation.

Total consumptive use by the several mixtures is nearly equal during the second and third weeks after irrigation. Water use rates decrease sharply in later weeks as components of the mixtures run out of available water and wilt. The great difficulty in distinguishing moisture changes caused by drainage from those produced by root absorption makes it impossible, for a considerable period after irrigation, to arrive at an accurate consumptive-use figure for deep rooted mixtures, especially those containing alfalfa. The slightly higher values reported for the alfalfa mixtures probably arise from this difficulty.

Soil-moisture records also indicate that consumptive-use rates are little affected by height of regrowth or even by removal of most of the shoot through clipping. Clover-grass mixtures clipped 12 days prior to sampling used water at essentially the same rate as plots of the same mixture clipped 25 days previously. Dr. L. D. Doneen, in unpublished studies with alfalfa, and more recently the authors working with ladino clover have found that plants cut at heights of about three inches extracted soil moisture at approximately the same rate as unclipped plants.

These findings of nearly equal consumptive-use rates by mixtures of distinctly different botanical composition and in different stages of regrowth are in agreement with other studies by the Department of Irrigation at Davis which have indicated that water use by plants is dependent primarily upon weather conditions. This same idea has been expressed by Thornthwaite (9) and by Schofield (8). As Schofield has stated it, the maximum rate of water loss from plants depends almost entirely on meteorological conditions (primarily incident solar radiation) and scarcely at all on the nature of the vegetation so long as it is in a stage of vegetative growth and effectively covers the soil. To Schofield's statement should be added the further condition that the plants are amply supplied with readily available water.

The consumptive-use rates reported here were obtained during the hot, dry summer months of July and August in the interior valley of California at Davis. During this period the average meteorological conditions were as follows: maximum temperature 93°F, minimum temperature 53°F, relative humidity at 7:00 A.M. 73%, solar radiation as measured by an Eppley pyrheliometer 676 gram-calories per square centimeter per day, and evaporation from a

standard United States Weather Bureau Pan (Type A) 3.5 inches per day.

Sizable differences in forage production have been obtained from the several legume-grass mixtures and from a given mixture under the various clipping frequencies (Peterson and Hagan). The ladino clover-grass mixture when cut at two-week intervals produced 5.59 tons per acre (at 12% moisture) but 8.00 tons at five-week intervals. Alfalfa-grass produced 3.72 tons with two-week clipping and 10.30 tons with five-week clipping. Despite these differences in yield, there were no detectable differences in consumptive-use rates. This is not surprising if one recalls that transpiration rates do not increase with height of stand as long as the soil surface is covered and that only a small fraction of the water lost from the soil is retained in the crop. A yield difference of 10 tons of hay per acre (at 12% moisture) would account for scarcely 1% of the total water consumptively used during the growth period if the use rate averaged 0.25 inch per day. The longest clipping periods have consistently given the highest yields for any given mixture sown. The advantage of less frequent harvesting from a water economy standpoint is readily seen if yields are considered in terms of production per unit of water consumed.

SUMMARY

Soil-moisture extraction records have been obtained for mature irrigated pasture mixtures growing on relatively deep alluvial soil as a means of evaluating the depth distribution of absorbing roots.

The mixtures containing a legume and several grasses were clipped at intervals of two, three, four, and five weeks during the growing season for three years. Soil-moisture extraction data were obtained in the third year during the fourth and fifth months after beginning differential clipping for the season. These data indicate that if the botan-

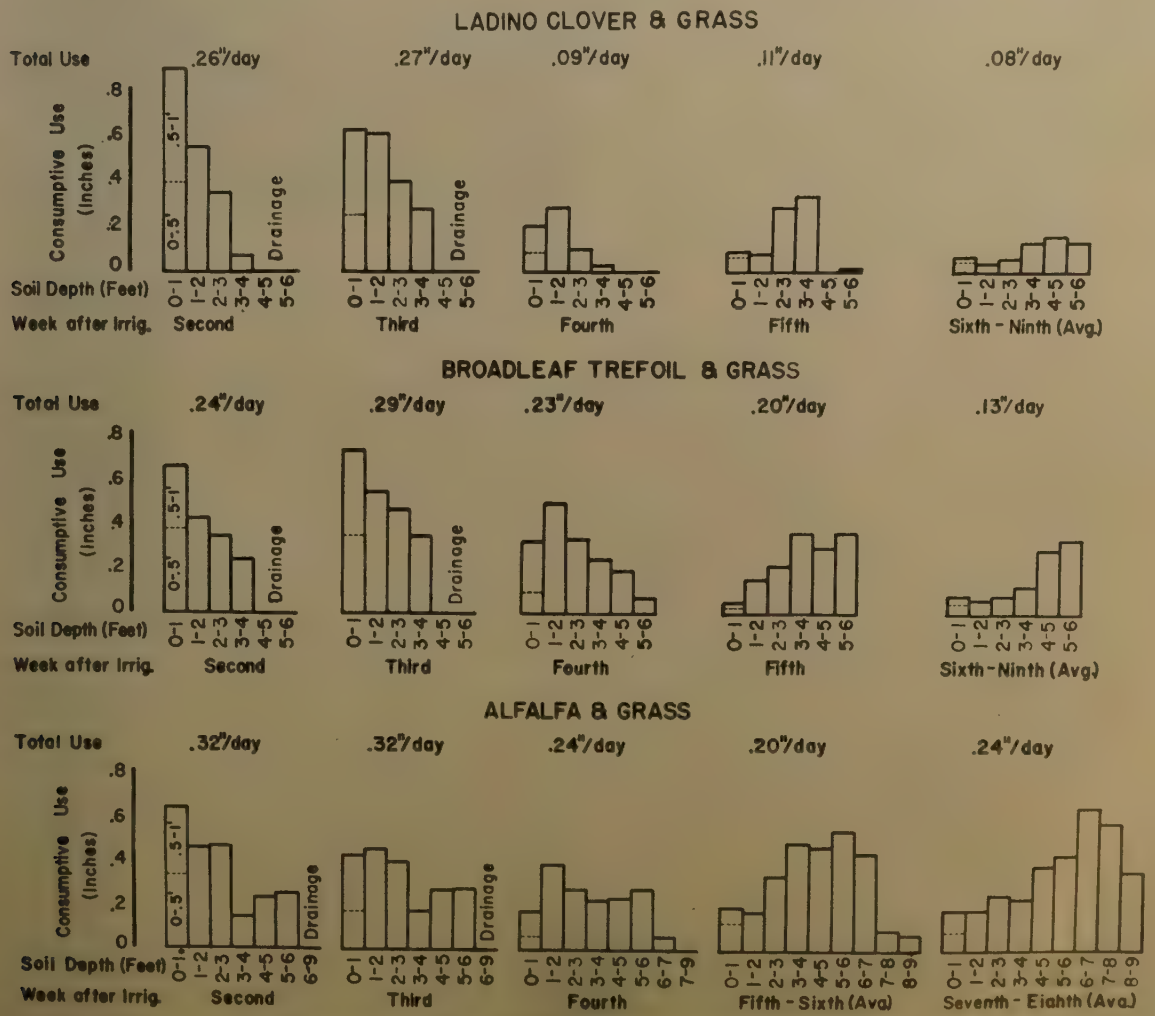

FIG. 3.—Consumptive use from various soil depths by three legume-grass mixtures for weekly periods following irrigation.

ical composition remains nearly constant there is no material effect on the distribution of absorbing roots in ladino clover-grass and broadleaf trefoil-grass mixtures. Moisture extraction under the clover-grass mixtures was largely confined to the top four feet of soil while under the trefoil-grass appreciable extraction occurred throughout the six-foot depth of soil for which records were obtained. The clipping schedules produced no measurable differences in rooting under alfalfa-grass mixtures in the top 8 feet below which a clay layer interferred with root activity.

Because of differences in effective depth of rooting, moisture extraction in the surface three feet of soil was most rapid under ladino-grass mixtures, less rapid under trefoil-grass, and the slowest under alfalfa-grass. Irrigation intervals must be established on the basis of moisture conditions within the root zone of the shallowest rooted component to be maintained in the forage mixture.

Consumptive-use rates were little affected by the botanical composition of the pasture mixtures and averaged nearly 0.3 inch per day during the hot, dry summer months of July and August at Davis, California. This value may be considered as the approximate maximum use rate for the climatic region in designing the capacity of irrigation systems.

The large differences in yields obtained under the several clipping frequencies with these pasture mixtures, for which the consumptive-use rates are nearly equal, lead to correspondingly large differences in forage production per unit of water consumed—a consideration of importance in regions of limited water supply.

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Differential Varietal Response of Root Tissues to Exogenous Growth Regulators in Soybeans, Oats and Corn[1]

J. H. Williams[2]

THE use of plant growth regulators in weed and crop control has become an accepted agricultural practice. The apparent selectivity of growth regulating substances, in general, and 2,4-dichlorophenoxyacetic acid in particular, exhibited between species of plants has resulted in wide usage of such substances as herbicides. A number of investigators have indicated that crop varieties or strains also may differ in response to exogenous growth regulators (1, 2, 3, 4, 5, 7, 8, 9, 12, 13).[3] However, in many of these experiments only a few varieties have been tested so that only a limited amount of the available genetic material has been sampled. Other studies, often involving the same varieties, have shown conflicting results. In this study, a large number of varieties of soybeans and oats and inbred lines of corn were screened by a laboratory root suppression test to determine differences in response to exogenous growth regulators. By use of this root inhibition test a wide range of germ plasm could be examined and classified as to relative tolerance to specific growth compounds. This technique has certain limitations as it ignores the importance of morphological characteristics of above ground plant parts in determining differential response to chemicals. 2,4-dichlorophenoxyacetic acid, 2,4,5-trichlorophenoxyacetic acid, isopropyl N-phenylcarbamate and naphthalene acetic acid[4] were selected to test differential varietal response.

METHODS AND MATERIALS

Seed of 93 varieties of soybeans was chosen to represent a wide range of germ plasm used in the breeding programs in the North Central and Southern regions. Varietal responses to 2,4-D were studied by subjecting germinating seeds to several concentrations and measuring length of the primary root after a given time had elapsed. Preliminary tests were designed to determine germination technique, concentrations of 2,4-D, optimum sample size, and number of replications necessary to measure differences among varieties.

Seeds of each soybean variety were germinated for 24 hours between filter paper moistened with 15 cc. of distilled water. Sprouted seeds of uniform stage of germination were selected and transferred, ten to a dish, into distilled water and into three aqueous solutions of the sodium salt of 2,4-D at concentrations of 0.5, 1.0 and 2.5 ppm. The petri dishes were placed in a dark germination room at 27° C. for 72 hours. The obviously diseased seedlings were discarded and seven of the remaining seedlings were taken at random for measurement. The length of the hypocotyl and root measured from the coyledon to root tip was used as the criterion of growth.

Treatment on each variety was replicated four times in successive days. From 12 to 15 varieties were included in each of six groups since this number was the maximum that could be measured in any one day. The total root length of seedlings grown in 2,4-D solutions was expressed as a percentage of the root length of the check, and statistically analyzed by standard procedures. Among the 93 varieties tested, 28 representing a range of relative root response were selected for a second test to obtain a more critical evaluation of varietal differences. Two groups each with 13 soybean varieties also were treated with 2,4-D, 2,4,5-T and IPC to compare the effects of these chemicals on root growth inhibition.

The same general techniques with a few alterations were employed to test varieties of oats. A total of 142 varieties representing 13 species was included in this study. Grains were germinated between two pieces of Wrenns blue-gray blotting paper moistened with 17 cc. of the sodium salt of 2,4-D solution and were allowed to grow four days at 23° C. before the length of the first primary root was measured. Preliminary measurements indicated a high correlation between growth of the first primary root and the total of primary roots and seminal roots. Because of questionable germination in some of the species of oats, nine grains were planted and six seedlings were taken at random for root measurement.

Concentrations of 2,4-D used ranged from 1.0 to 7.5 ppm. From among the 142 varieties screened in the first test 41 were selected for further evaluation on the basis of their response in the 5.0 and the 7.5 ppm. concentrations. An additional concentration of 10 ppm. was added to obtain further information, particularly on the more resistant varieties. The technique used was the same except that varieties were tested with five replications. Forty varieties also were tested with IPC at concentrations from 0.2 to 0.5 ppm. A group of 20 oat varieties was treated with 7.5 ppm. 2,4-D; 7.5 ppm. 2,4,5-T; 0.3 ppm. IPC; and 15 ppm. NAA. These respective concentrations resulted in a similar degree of root growth inhibition.

Preliminary studies with inbred lines of corn indicated that filter paper was satisfactory for seed germination. Nine kernels, previously treated with Panogen diluted to 25 ppm. mercury to reduce microorganism injury and rinsed in distilled water, were placed between filter paper and moistened with 13.5 cc. of solution. After 96 hours in a constant temperature room held at 27° C. the pri-

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[3] Numbers in parenthesis refer to "Literature Cited."

[4] Subsequent reference to these chemicals will be made with their abbreviated forms 2,4-D, 2,4,5-T, IPC and NAA, respectively.

Table 1.—Frequency distribution of relative seedling root length in percent of the distilled water check for 93 soybean varieties germinated and transferred to .05, 1.0, and 2.5 ppm. of sodium salt of 2,4-D.

Concentration in ppm.	Relative Root Length in Percent of Check														Mean of 93 Varieties
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	
0.5			1	3	1	1	3	16	29	23	11	5	3	1	62.8
1.0					3	16	27	27	5	8	2	1			52.8
2.5	5	9	22	26	19	8	3	1							34.8

Table 2.—Frequency distribution of relative seedling root length in percent of the distilled water check of 142 oat varieties germinated in 1.0 to 7.5 ppm. solution of the sodium salt of 2,4-D.

Concentration in ppm.	Relative Root Length in Percent of Check											Mean of 142 Varieties
	15	25	35	45	55	65	75	85	95	105	115	
1.0				1	0	0	7	49	57	19	9	93.0
2.5		1	2	4	11	23	49	38	20	5		78.6
5.0	1	0	2	23	32	39	23	16	6			63.6
7.5	2	12	21	28	36	25	9	9				51.3

mary roots of six seedlings, taken at random, were measured. A total of 119 inbred lines was tested with four replications using 2,4-D concentrations of 0.25, 0.50, 1.0 and 2.5 ppm.

As in the tests with soybeans and oats, 38 lines were selected on basis of high and low tolerance for further tests with 2,4-D and IPC. Concentrations of IPC used were 1.5, 2.0, 3.0 and 4.0 ppm.

EXPERIMENTAL RESULTS

Soybeans

The response of 93 lines of soybeans was evaluated in seven groups by the root growth suppression test. A summary of response expressed as relative root length in percent of the untreated check is shown in table 1. Within each of the levels of 2,4-D concentrations rather wide differences were obtained among the varieties tested. The analysis of variance was made independently at each level of concentration since the major factor for evaluation was varietal differences rather than the interaction of varieties × concentrations. Differential response of varieties was not exhibited in all groups nor at all levels of 2,4-D. The highest concentration (2.5 ppm.) appeared to be the most desirable for separating the varieties in respect to their response.

From the original test of 93 varieties, 28 were chosen to represent a full range in response to 2,4-D. These were retested by similar techniques with four concentrations of 2,4-D. The frequency distributions of their relative root length in each of the four levels of concentration suggest, as in the first test, that a threshold concentration of about 2.5 ppm. is necessary to differentiate the varieties into separate genotypes.

For one group of 14 selected varieties, a combined analysis was made for response at the four levels of 2,4-D. The mean square for varieties when tested against the error mean square (varieties × replications) was highly significant, indicating a differential varietal response. The analysis of variance did not reveal a significant variety-concentration interaction.

Correlation coefficients were calculated to determine the degree of association between the response of varieties in the first and second tests. These correlations, 0.38, 0.78 and 0.63 between two tests in 0.5 ppm., 1.0 ppm. and 2.5 ppm., respectively, indicate that a reasonably good duplication of results was obtained at the higher concentrations.

Two groups each with 13 soybean varieties also were treated with 2,4-D, 2,4,5-T and IPC in a separate test to determine the degree of varietal response to different chemicals. The analysis of variance indicated that significant differences in varietal response were obtained for 2,4,5-T in both groups but only for varieties treated with 2,4-D and IPC in the second group. Highly significant correlations were obtained between varieties treated with 2,4-D and 2,4,5-T (0.76) but low correlations were obtained between varieties treated with 2,4-D and IPC (—0.011) and 2,4,5-T and IPC (0.003).

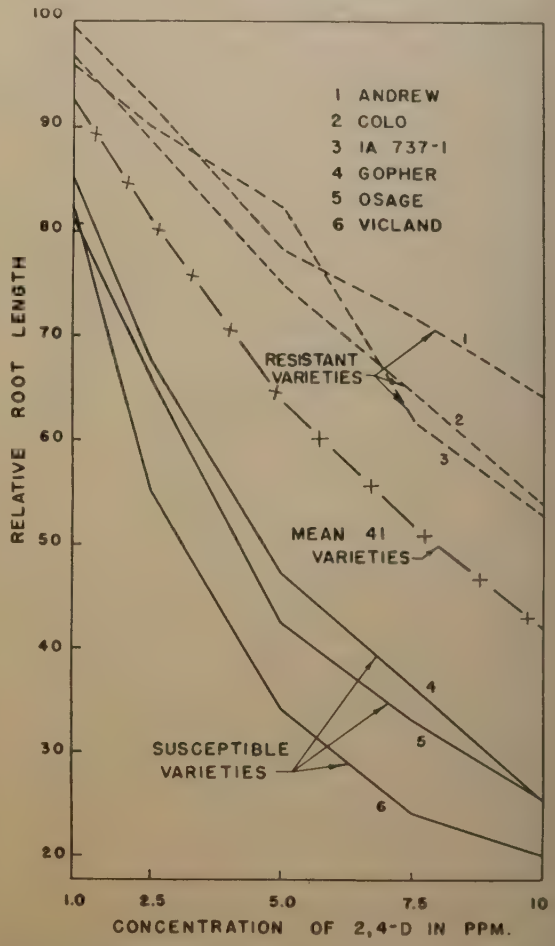

FIG. 1.—The relative response to 2,4-D of three tolerant and three susceptible oat varieties compared with the mean of 41 oat varieties as measured by inhibition of root growth.

Oats

Results of preliminary tests provided the basis for the techniques used to screen 142 varieties of oats for differential response. Seven groups containing from 16 to 24 varieties were tested with 1.0, 2.5, 5.0 and 7.5 ppm. of 2,4-D using inhibition of the growth of the primary root to measure response as compared to growth in the distilled water check. The frequency distribution of the relative root length is presented in table 2. It was noted that, as in the case of soybeans, there was a considerable range in response among varieties within each concentration.

In all groups, varietal differences were highly significant when tested in the 7.5 ppm. 2,4-D solution and in all but one group in the 5.0 ppm. solution. At the lower concentrations varietal response was less consistent and in several groups the variety mean squares were non-significant. Thus, it appears that a concentration of 7.5 ppm. of 2,4-D is necessary to separate consistently the oat varieties into distinct genotypes.

A combined analysis of variance calculated for a group of varieties subjected to five levels of concentration indicated that varieties did not react in the same manner to the different concentrations. The frequency distribution of 41 selected varieties showed the range of varietal response at each concentration was large. For example, in 10 ppm. of 2,4-D the varieties ranged from 15 to 65% of the root length in the distilled water check; at 2.5 ppm. one variety showed some stimulation while the growth of another was reduced to 55%. Significant differences at 1% level were obtained in all instances except one. It appeared that oat varieties varied more in response to 2,4-D than did the soybean varieties.

Correlation coefficients were calculated to ascertain the association of variety response in the first and second test. The correlations in the 2.5, 5.0 and 7.5 ppm. concentrations were 0.43, 0.54 and 0.49, respectively, all highly significant. Varieties for the second test were chosen from those that had given high, medium and low tolerance in the first test. Although the resistant varieties generally remained high in rank and the susceptible varieties low in rank, there was considerable variation in response among the intermediate group. A negative correlation of —0.34 was obtained between the two tests at 1.0 ppm. concentration, possibly because variety response was not great at this concentration.

Among the various oat species included in the test none appeared more tolerant than varieties of *Avena sativa*. However, several varieties of the species *A. nuda* appeared more susceptible than other species. Two oat varieties of *A. sativa* which has been chosen as tolerant and two as susceptible were dehulled and tested with the non-dehulled seed of the same varieties and one of the most susceptible *A. nuda* varieties. It was found that Vicland, a susceptible *A. sativa* variety, was reduced to a similar percent inhibition as the *A. nuda* type. Colo, a more resistant variety, also was somewhat less tolerant when dehulled but held its relative position in tolerance to 2,4-D in comparison with hulled seed of Vicland.

Six varieties, including high and low in tolerance, were retested in a range of concentrations from 2.5 to 30.0 ppm. to study differential effect of the higher concentrations on the two types of varieties. The mean response of the three more tolerant varieties was approximately twice the mean value for the susceptible group at all concentrations. The relative response of each of these six varieties is compared to the mean of the 41 selected oat varieties in figure 1.

Forty of the 41 oat varieties treated with 2,4-D were tested with IPC using the same general techniques as previously described. The most effective concentrations of IPC to measure varietal response, determined in preliminary studies, ranged from 0.2 to 0.5 ppm. As in the tests with 2,4-D there was a wide range in varietal response. The analysis of variance of the relative root length within each concentration showed that variety mean squares were highly significant in all concentrations used.

In order to determine the relationship of the varietal response to the two exogenous growth regulators, the analyses of variance of the 21 varieties included in the same group and tested with 7.5 ppm. 2,4-D and 0.3 ppm. IPC were combined. These two concentrations were chosen because they resulted in a similar average root inhibition. The most important part of the analysis was the highly significant mean square for varieties × chemicals when tested against the error term varieties × chemicals × replications. These data indicate that oat varieties did not respond in a similar way to the two growth regulators.

This same procedure was duplicated with the second group of 19 oat varieties tested with the two chemicals and the results were in complete agreement with the first combined analysis. A correlation coefficient of —0.007 was calculated between the 40 varieties tested with 2,4-D and with IPC. This further substantiated evidence that oat varieties differed in response to the two chemicals. This relationship may be an important basic biological fact; for, on the basis of these data it would be possible to select varieties that are relatively tolerant to 2,4-D but relatively susceptible to IPC.

In the separate test with 20 oat varieties treated with 2,4-D, 2,4,5-T, NAA and IPC, differential varietal response was noted with each of the four chemicals. Highly significant and positive correlations (table 3) were obtained among the varieties treated with 2,4-D and 2,4,5-T and between 2,4-D and NAA. The trend toward a negative association between response to 2,4-D and IPC agrees with previous data from these comparisons.

Corn

In a manner similar to the studies with soybeans and oats, preliminary experiments were undertaken to determine the techniques to be used for testing corn inbreds. The results of studies with 119 inbred corn lines are summarized in table 4. The frequency distribution of the inbreds tested

Table 3.—Correlation coefficients between the 20 oat varieties treated with four different growth regulating substances.

Treatment	Correlation Coefficient
2,4-D vs 2,4,5-T	0.60**
2,4-D vs NAA	0.86**
2,4-D vs IPC	—.32
2,4,5-T vs IPC	—.40
2,4,5-T vs NAA	.37
IPC vs NAA	.16

** Significant at the 1 percent level of probability.

Table 4.—Frequency distribution of relative root length of 119 inbred lines of corn subjected to the sodium salt of 2,4-D in concentrations ranging from 0.25 ppm. to 2.5 ppm.

Concentration in ppm.	Relative root length in percent of the check										Mean of 119 Lines
	15	25	35	45	55	65	75	85	95	105	
0.25				1	4	24	55	23	11	1	76.0
0.50			4	12	36	45	18	4			61.0
1.0		10	28	33	34	10	4				46.5
2.5	11	50	35	19	3	1					30.7

shows a wide range of variation at all levels of 2,4-D used in the investigation. The analysis of variance indicates that differential varietal response occurred within each of the four concentrations. In order to determine if the varieties responded the same at all levels of concentration a combined analysis of variance was made for one group of 18 inbred lines of corn. As in the case with oats, there was a highly significant interaction between varieties and concentrations indicating that varieties differed in their reactions at each level of 2,4-D.

As in previous tests, 19 tolerant and 19 susceptible inbreds were selected and retested using four replications. It was noted that although the varieties were chosen on this basis, the distribution of the 38 lines in the second test was not bimodal. Highly significant correlation of 0.65, 0.77, 0.78 and 0.83 were obtained between the two tests for the 0.25 ppm., 0.50 ppm., 1.0 ppm. and 2.5 ppm., respectively.

A group of 36 inbred lines also was tested with IPC at 1.5, 2.0, 3.0 and 4.0 ppm. A considerable range in varietal response was found and the analysis of variance showed that varieties differed significantly at each level of IPC.

The analyses of variance of the 16 varieties included in the same group and tested with 1.0 ppm. of 2,4-D and 3.0 ppm. of IPC were combined to determine the relationship of the varietal response of inbred lines of corn to the two exogenous growth regulators. As in the combined analysis involving oat varieties, the mean squares for varieties and for varieties $\times$ chemicals when tested against appropriate error terms were significant at the 1% level. These data indicate that the inbred lines of corn did not respond in a similar way to the two chemicals. The analyses of variance of the second group involving 20 inbred lines tested with 2,4-D and IPC were combined in the same manner and the results agreed closely with the first group. A correlation coefficient of 0.201 was obtained between the 35 varieties treated with 2,4-D and IPC. These data show further evidence that lines of corn, like oat varieties, differ in their response to the two plant growth regulators.

DISCUSSION

The bio-assay method has been used to determine unknown concentrations of growth substances (6, 10) and to determine effectiveness of different chemicals on plant growth (11). In this study this laboratory technique permitted the ranking of a large number of varieties in response to growth regulating substances. It was demonstrated that differences in varietal response to exogenous growth regulators do exist as measured by inhibition of root growth of germinating seedlings. The fact that varieties, which were chosen as high and low in tolerance to

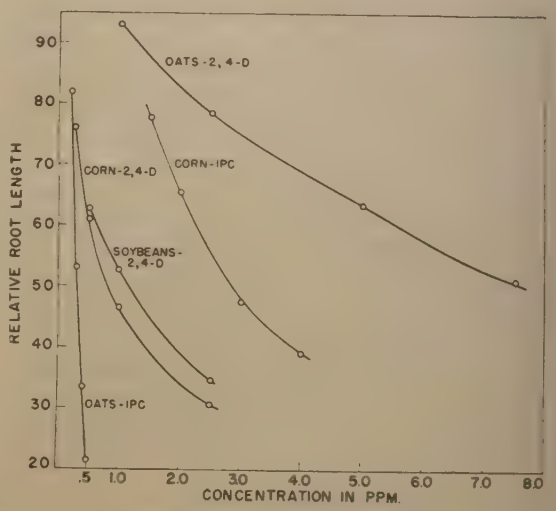

FIG. 2.—Comparative response of corn, soybeans and oats to 2,4-D and of corn and oats to IPC.

2,4-D in each of the three crops studied, responded in a similar way in subsequent tests indicates that this method offers an opportunity to rank varieties consistently when tested under comparable conditions. It appeared that corn lines and oat varieties displayed a greater range of response than soybeans and could be separated more consistently into distinct genotypes.

The mean response of varieties in the three crops to 2,4-D and IPC as measured by root suppression is shown in figure 2. The growth of soybean varieties and inbred lines of corn appear to be equally inhibited by a similar range of concentrations of 2,4-D. However, the technique for testing and measuring the response of these species to growth regulators differed. The soybean seeds were germinated in distilled water and transferred to 2,4-D solutions; the corn kernels were germinated initially in the various concentrations. The length of the root and hypocotyl was used as measurement of inhibition of growth of soybeans while only root tissue was used as measurement of inhibition of the corn inbreds. Therefore, the results of the two tests are not comparable. Stem tissue of cucumbers has been shown to be less sensitive to 2,4-D than the root tissue (6). Similar differences were observed in the soybean in this investigation.

Oat varieties required a concentration of 2,4-D about 10 times as great to inhibit root growth to the same degree as

corn but only one-tenth as great a concentration of IPC, as shown in figure 2.

Apparently the response of the less commonly grown species of *Avena* is not different from *A. sativa* and therefore offer little possibility as parental material in breeding for greater tolerance to 2,4-D. *A. nuda* varieties appeared to be less tolerant to 2,4-D than other species. However, when the susceptible *A. sativa,* Vicland, was dehulled and compared to the most susceptible variety of *A. nuda* the response of the two was not different.

In the experiments with oat and soybean varieties and inbred lines of corn it was found that varieties responded differently to 2,4-D and also to IPC. This indicates the possibility of developing varieties which would vary in tolerance to either of these specific plant growth regulators. But of greater importance was the fact that varieties differed in their tolerance to the two compounds. For example, the oat variety, Vicland, was found to be one of the more susceptible to 2,4-D, but was one of the most tolerant to IPC. Apparently there is an association between varietal response to 2,4-D, 2,4,5-T and NAA as indicated by the high correlations obtained for varieties treated with these chemicals. This relationship of response to plant growth regulators could possibly exist between other selective herbicides and could become an important principle in breeding for tolerance to various exogenous growth regulators used to control weeds. Development of crop varieties which are relatively resistant to specific plant growth regulating compounds offers a possible method of increasing the effectiveness of 2,4-D and other synthetic compounds as selective herbicides by increasing the differences between tolerance of crop varieties and susceptibility of the undesirable plants.

It is possible, however, that varietal differences within each crop which are statistically significant in a laboratory test would not be economically important under field conditions. Even if large differences exist, the variety-environment interaction might be great enough to offset the effects of differential response of varieties. This laboratory test also fails to account for inherited morphological differences between species and varieties which may result in an apparent selective action of the chemical.

SUMMARY

A total of 93 varieties of soybeans, 142 varieties of oats and 119 inbred lines of corn were tested by laboratory root suppression tests to determine their relative tolerance to 2,4-D. Differential response was found to exist among varieties within each of the three crops studied. A greater range in response, however, was noted among oat varieties and corn inbreds than among soybean varieties. Other species of *Avena* did not show greater tolerance to 2,4-D than common varieties of *A. sativa.*

Forty selected varieties of oats representing various levels of tolerance to 2,4-D were screened for response to IPC by the root suppression test. A wide range of response to this chemical also was found. Oat varieties did not respond in a similar way to the two chemicals.

Thirty-eight selected corn inbreds representing varying levels of tolerance to 2,4-D were found to differ significantly in response to IPC. Inbred lines of corn also did not respond in a similar way to 2,4-D and IPC.

Among varieties of all three crops high positive correlations were found between response to 2,4-D, 2,4,5-T and NAA, but negative or low correlations were obtained between response to IPC and the other chemicals investigated.

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Inheritance of Differential Response of Corn Root Tissues to 2,4-D.[1]

J. H. Williams and I. J. Johnson[2]

THE increased use of chemical methods for weed control in cultivated crop plants has led to investigations concerning possible differences in varietal response. Studies with oats[3] [4] (4, 8, 12, 13, 16, 17) have shown that varieties do not respond in a similar manner to growth regulating substances while other investigations (2, 3, 5) have failed to measure such differences. Several studies with corn[4] (1, 6, 7, 9, 10, 11, 14, 15) also have shown that differences exist among inbred lines and that differences may be transmitted to crosses among them. Differential response of varieties in other crops also has been reported in the literature. These studies have led to the general viewpoint that differences may exist in the genotype of crop varieties in respect to their physiologic response to exogenous growth regulators.

Because the effectiveness of weed control by chemical means depends upon the relative susceptibility of cultivated and weedy plants, it may become necessary for the plant breeder to develop varieties with greater tolerance to minimize damage to the crop in question. Knowledge of the mode of inheritance of differential response becomes an important asset in a breeding program.

MATERIALS AND METHODS

A survey was made with 119 inbred lines of corn to test their response to several exogenous growth regulating chemicals, including 2,4-D. Response was determined by subjecting germinating grains in petri dishes to several concentrations and measuring the length of the primary root after 4 days of exposure. Relative response was expressed as the ratio of root length of the treated and nontreated check. From this group of inbreds four lines were chosen, two relatively tolerant and two relatively susceptible to 2,4-D as measured by the root-suppression test. Root inhibition is obviously only one type of expression of genetic response and does not take into consideration tolerance or susceptibility due to inherited morphological characteristics of the above-ground parts of plants.

The crosses or backcrosses included in this phase of the study are shown in the chart at the bottom of this page.

Approximately 300 plants of each of the 4 F_2 and 250 plants of each of the 2 backcross populations chosen at random were self-pollinated to obtain F_3 and BC_1S_1 seed. From these 6 populations approximately 140 progenies of each were tested for relative root response.

A group of nine inbred lines representing a range from tolerant to susceptible in response were crossed reciprocally in all possible combinations to study possible maternal effects in the F_1 generation.

Ten kernels of all progenies, previously treated with a disinfectant,[5] were germinated in 152 mm petri dishes to which was added 12 cc of a 2.5 ppm solution of the sodium salt of 2,4-D. This concentration was found in previous studies to give a satisfactory differential response with the parental inbred lines. A similar test was made at the same time using distilled water as a check treatment. Petri dishes were placed in a dark, constant temperature room held at 80° F for 4 days and the root length of six representative seedlings from the 2,4-D and check treatments were measured in millimeters. Each of the F_3 and BC_1S_1 seedling progenies was replicated four times and the reciprocal F_1 crosses and their parents were replicated six times.

Because it was not possible to test one replication of all segregating progenies (F_3 and BC_1S_1) in a single set or even to include as many as 140 entries in a single group, each population was divided arbitrarily into two or three groups. To permit comparisons to be made among groups within populations, the two parents and the F_1 were included as uniform entries in each group. To enable comparisons to be made among crosses, two additional inbreds were included as standard entries for all groups in the entire study. Adjusted means were used for entries within a population group if the analysis of variance of the uniform checks showed a significant difference between groups. In a similar way, adjusted means were used for crosses if the analysis of variance of the two uniform entries were found to differ significantly among populations. Only minor adjustments were found to be necessary since all groups within crosses and all crosses were tested at the same temperature, time and 2,4-D concentration.

EXPERIMENTAL RESULTS

Segregating Populations

From the analysis of variance of relative root length, the genetic component of variance was calculated for each group within a specific population as shown in table 1. These components of variance provided an estimate of differences in genetic variance among the six segregating

Cross	Parental response*	Parental classification
B21 × WF9	36.5 × 54.9	Tolerant × tolerant
A25 × Ia153	23.1 × 28.9	Susceptible × susceptible
WF9 × A25	50.4 × 21.4	Tolerant × susceptible
B21 × Ia153	39.5 × 30.9	Tolerant × susceptible
(B21 × Ia153 Ia153	(42.6 × 29.9)29.9	(Tolerant × susceptible) susceptible
(B21 × Ia153)B21	(49.9 × 33.4)49.9	(Tolerant × susceptible) tolerant

* Response for parents when included in these specific crosses.

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[5] Panogen.

Table 1.—Summary of analyses of variance of two groups of F_3 lines from the cross A25 × Ia153 and the expected components of variance.

Source of variation	d.f.	Group 1	Group 2	Combined	Expected mean squares
		Mean squares			
F_3 entries	69	96.49	86.14	91.31	$\sigma^2E+4\sigma^2F_3$
Error	207	40.18	30.88	35.33	σ^2E
		Components of variance			
σ^2F_3		14.08	13.82	13.94	

populations as related to parental response to 2,4-D. A summary of genetic variances for each of the six crosses is shown in table 2.

The data in table 2 show that the population mean of the F_3 lines from the cross between tolerant parents (B21 × WF9) was considerably higher than the F_3 lines from the cross between susceptible parents (A25 × Ia153) and that the two F_3 populations between tolerant and susceptible parents were intermediate between these values. These differences also are shown as frequency distributions in figures 1 and 2. The components of genetic variance were in reasonably good agreement with expectation. The lowest variances were obtained in the cross of susceptible parents and in the two BC_1S_1 populations, suggesting a relatively small amount of segregation in these populations in comparison with the F_3 lines from crosses between tolerant and susceptible parents. The genetic variance among F_3 lines in the cross between tolerant parents was relatively high. As shown in figure 2, the relative root length of F_3 lines from this cross ranged from 19 to 59% of the untreated check. In this cross, a large proportion of the F_3 lines were more susceptible than either parent, suggesting that these two lines differ in genotype, resulting in transgressive segregation for susceptibility. In a subsequent section of this report on comparisons of F_1 and parental response, the data show partial dominance for susceptibility. On this basis, a wide range of segregation toward susceptibility might be expected among F_3 lines from crosses between parents differing in genotype for tolerance to 2,4-D.

The comparative frequency distributions for F_3 and BC_1S_1 lines from the cross B21 × Ia153 between tolerant and susceptible inbred lines are shown in figure 1. Each of these 3 distributions was based on approximately 140 progenies. F_3 lines ranged from a relative root response of 19 to 59, with a mean of 35.7. The mean responses of the 2 parents and the F_1 cross were 39.5, 30.9, and 34.2,

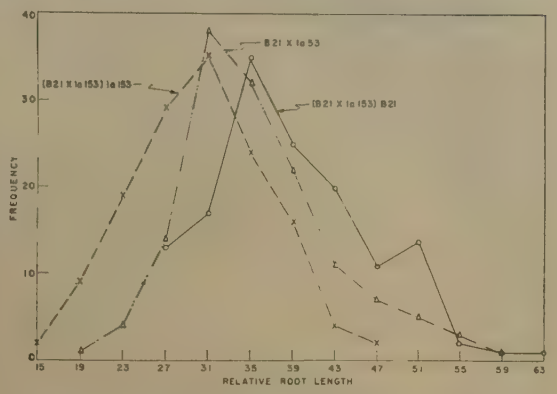

FIG. 1.—Frequency distribution of F_3 and BC_1S_1 generation lines from the cross B21 (tolerant) × IA153 (susceptible) inbred parents.

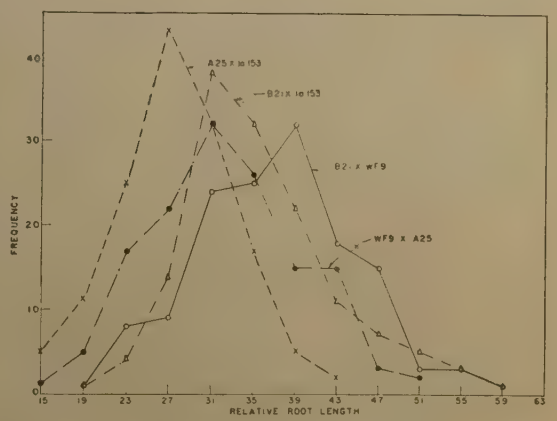

FIG. 2.—Frequency distribution of F_3 lines from four crosses representing tolerant × susceptible (B21 × IA153 and WF9 × A25), tolerant × tolerant (B21 × WF9), and susceptible × susceptible (A25 × IA153) inbred parents.

respectively. The BC_1S_1 lines derived by backcrossing to the tolerant parent ranged from 27 to 63, with a mean of 38.9, and the BC_1S_1 lines from the backcross to the susceptible parent ranged from 15 to 47, with a mean of 30.3. The F_3 distribution was slightly skewed toward susceptibility.

Table 2.—Expected components of variance and population means for F_3 and BC_1S_1 lines.

Crosses	Parental response	Generation	σ^2F_3	Population means
B21 × WF9	T × T	F_3 lines	47.0	37.2
WF9 × A25	T × S	F_3 lines	24.9	32.4
B21 × Ia153	T × S	F_3 lines	38.1	35.7
A25 × Ia153	S × S	F_3 lines	14.0	27.8
(B21 × Ia153) B21	(T × S) T	BC_1S_1 lines	16.9	38.9
(B21 × Ia153) Ia153	(T × S) S	BC_1S_1 lines	17.3	30.3

Table 3.—Mean relative root response to 2,4-D of all possible reciprocal single crosses among nine inbred lines of maize. (Means based on six replications).

		B13	L289	WF9	K5 × WF9	A25	Pr(Osf (Hy)	C103	Lan W39136	Tr	Mean
B13	Female	——	33.5	——	41.5	——	30.3	26.2	25.0	33.8	31.7**
	Male	——	32.7	47.3	41.0	21.2	25.5	17.7*	17.7	26.2*	26.8
L289	Female	32.7	——	42.7	44.8	29.5	30.3	17.5	27.3	32.6	32.2
	Male	33.5	——	50.0	47.6	28.0	24.8	20.5	26.8	29.3	32.6
WF9	Female	47.3	50.0	——	53.2	33.8	33.7	16.1	40.2	33.2	37.5
	Male	——	42.7	——	55.7	30.3	31.0	27.7*	40.3	29.8	36.8
K5 × WF9	Female	41.0	47.6	55.7	——	43.8	37.2	21.2	38.0	41.6	40.8
	Male	41.5	44.8	53.2	——	37.6	34.3	27.3	32.3	35.0	38.3
A25	Female	21.2	28.0	30.3	37.6	——	24.6	14.8	21.3	21.2	25.4
	Male	——	29.5	33.8	43.8	——	20.5	22.3*	19.2	20.5	27.1
Pr(Osf(Hy)	Female	25.5	24.8	31.0	34.3	20.5	——	17.2	17.2	21.0	23.9
	Male	30.3	30.3	33.7	37.2	24.6	——	18.2	18.3	20.0	26.6
C103	Female	17.7	20.5	27.7	27.3	22.3	18.2	——	14.5	19.5	21.0
	Male	26.2*	17.5	18.1*	21.2	14.8*	17.2	——	18.8	18.7	19.0
LanM69136	Female	17.7	26.8	40.3	32.3	19.2	18.3	18.8	——	20.3	24.2
	Male	25.0	27.3	40.2	38.0	21.3	17.2	14.5	——	22.0	25.7
Tr	Female	26.2	29.3	29.8	35.0	20.5	20.0	18.7	22.0	——	25.2
	Male	33.8*	32.6	33.2	41.6	21.2	21.0	19.5	20.3	——	27.9
Inbred parents		39.5	37.5	56.0	63.3	26.0	20.3	19.0	29.2	25.0	——

* Reciprocals different at the 5% level of probability.
** Reciprocals different at the 1% level of probability.

In the frequency distributions of F_3 lines from 4 crosses, shown in figure 2, the population from the cross of susceptible parents (A25 × Ia153) ranged from 15 to 43, with a mean of 27.8. The 2 parents of this cross had relative responses of 28.9 and 23.1, respectively. Transgressive segregation might have existed in this cross, since the upper and lower limits of segregation exceeded the parental values. It is recognized that critical proof of transgressive segregation would depend upon the inclusion of a larger number of the two parents than used in this study. Distributions of the F_3 lines from the crosses between tolerant × susceptible parents (B21 × Ia153 and WF9 × A25) covered a wide range, including parental response.

Although it obviously is not possible to estimate from these data the number of genes conditioning response to 2,4-D, these results suggest that the mode of inheritance was not extremely complex. In crosses between tolerant and susceptible lines, parental response was recovered in populations of approximately 140 progenies. The distributions of the backcrosses were shifted toward their respective recurrent parents. These data would indicate that genes conditioning differential response could be transferred from a tolerant to a susceptible parent if desired in a breeding program.

Reciprocal Crosses

A study was made with reciprocal F_1 crosses to determine whether root response to 2,4-D might have been affected by the pericarp of the maternal parent.

A summary of the mean relative root response of reciprocal F_1 crosses among nine inbred lines, together with the inbred parents, is shown in table 3 and the analysis of variance in table 4. Although the mean squares for within crosses exceeded the 5% level of significance, there was very little evidence to indicate that reciprocal crosses differed in response. Only 4 of the 34 reciprocal crosses were different at the 5% level. In only two of these crosses the reciprocal crosses differed in response, as might be expected if the maternal tissue affected response of the F_1 cross; and in the other two crosses, the differences in F_1 response were in the opposite direction from that of the maternal parent.

Table 4.—Summary of analysis of variance of the relative root response to 2,4-D of reciprocal single crosses among nine inbred lines of maize.

Source of variation	d.f.	Mean squares
Replications	5	151.75
Entries	67	589.11**
Crosses	33	1130.68**
Within crosses	34	63.47*
Entries × replications	335	44.78
Crosses × replications	165	47.71
Within crosses × replications	170	41.93

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

This rather large number of crosses provided an opportunity to compare the response of the F_1 with that of the two parents. Highly significant differences were found among the 34 crosses (in which reciprocals were tested) and among the 9 inbred parents. In every cross between inbreds that differed in response, the F_1 was slightly more

susceptible than the parental average. The consistency of these results suggests partial dominance for susceptibility of root tissue to 2,4-D. The correlation between the parental average and F_1 response among the tolerant × susceptible crosses was 0.718, a highly significant value.

SUMMARY

1. Progenies derived from crosses between inbred lines of corn relatively tolerant and susceptible to 2,4-D were tested by use of the root suppression test to aqueous solutions of the sodium salt of 2,4-D. Populations used in this study included F_3 seedling progenies from one cross between tolerant parents, one cross between susceptible parents, and two crosses between tolerant and susceptible parents. BC_1S_1 progenies from backcrosses of a tolerant × susceptible F_1 to both parents also were tested.

2. Results from this study showed that populations of 140 F_3 lines were adequate to recover parental response in tolerant × susceptible crosses.

3. Indication of transgressive segregation for susceptibility was obtained among F_3 lines from the cross between tolerant parents.

4. In one cross between tolerant and susceptible parents in which F_3 lines and BC_1S_1 populations were studied, the F_3 mean was intermediate to the two parents, and the BC_1S_1 means were shifted toward their respective parents.

5. Components of genetic variance among progenies within crosses in general were lower for the cross between susceptible parents and the BC_1S_1 progenies than among progenies derived from crosses betwen tolerant and susceptible parents.

6. Important differences were not found between reciprocal F_1 crosses, suggesting that the maternal pericarp tissue probably did not have a significant effect upon seedling root response.

7. Root tissue response of the F_1 seedlings was slightly lower than the parental average, suggesting partial dominance for susceptibility to 2,4-D. Correlation between F_1 and parental mean was 0.718, a highly significant value.

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A Fifth Gene Conditioning Hessian Fly Response in Common Wheat[1]

R. G. Shands and W. B. Cartwright[2]

FOUR genes have been described as influencing reactions of common wheat to the hessian fly, *Phytophaga destructor* Say. Cartwright and Wiebe (4) showed that the resistance of Dawson in crosses with the susceptible varieties Poso and Big Club depended upon two genetic factors. Later, Noble and Suneson (5) isolated the Dawson factors in the third backcross of Dawson × Poso to Poso. Selection No. 6179 was designated as having the genetic constitution $H_1H_1h_2h_2$ while Selection No. 6232 was designated as $h_1h_1H_2H_2$. Caldwell, Cartwright, and Compton (1) presented evidence which showed that fly resistance of the common spring wheat variety, W38, was controlled by the incompletely dominant gene pair H_3H_3. Suneson and Noble (6) in genetic studies of Java found that its resistance to hessian fly depended upon the recessive gene pair designated as h_4h_4.

This paper presents data which show presence of a fifth gene pair in Ribeiro and other varieties that control resistance to the hessian fly native to Indiana. In addition, limited studies were made on the relation of fly response to stem-rust reaction and the presence or absence of awns.

METHODS AND MATERIALS

The crosses were made at Madison, Wis., where the F_1 and F_2 plants were grown. All of the hessian fly tests were conducted in the greenhouse during the winter period at Lafayette, Ind. Tests were carried on during the years of 1947, 1948, 1949, and 1951. The number of plants per test ranged from 20 to 30 for most F_3 families whereas the numbers for F_1 and F_2 generations were more variable.

Plants at the one-leaf stage were exposed to a heavy attack of hessian fly under cheesecloth tents as described by Cartwright and LaHue (2). Temperature was maintained at approximately 70° F. A specialized race of flies capable of infesting W38 was used in tests of 1947, 1948, and 1949, but an unselected or general population of Indiana flies was used in tests of 1951. At three weeks after exposure of plants to flies, the plants were classified as infested or noninfested depending on whether or not larvae or puparia were present. Throughout the inheritance studies, temperature and light conditions were satisfactory for reliable tests.

Only wheat varieties of spring-growth habit were used in these studies. A small part of the F_2 populations from crosses with Selections 6179 and 6232 showed winter-growth habit and failed to produce viable seed. The numbers of such plants were probably too small to upset inheritance ratios.

F_2 populations in 1946 and 1947 and backcrossed F_1 plants in 1947 were exposed to inoculum from spreader rows which had been inoculated with races 17, 19, and 56 of *Puccinia graminis tritici* Eriks. and Henn.

The wheat varieties used in tests and their geographic origin are listed in table 1. The selection of Ribeiro used in this work is a common wheat. Unnamed P.I. 94549–6 and unnamed P.I. 94571–14, also common wheats, have leaf sheaths that are light green in color and the two varieties are very similar in growth habit and other characters.

EXPERIMENTAL RESULTS

The purpose of this work was to determine the inheritance of hessian fly response of Ribeiro P.I. 56206–8, unnamed P.I. 94549–6, and unnamed P.I. 94571–14 and whether or not resistance factors in these wheats were different than those previously described. The three wheats were crossed with each other, with Thatcher, and with tester varieties having the previously described genes. Seedling tests were made for fly response on the F_2 and F_3 generations of all crosses and on the F_1 for part of the crosses.

F_1 Seedling Response

The F_1 responses of seedling plants are given in table 2. F_1 plants from reciprocal crosses of Ribeiro and P.I. 94549–6 with Thatcher showed no significant difference in fly response. In crosses of the three varieties with Thatcher, infestation of F_1 plants ranged from 33 to 67% and stunted plants occurred in crosses involving Ribeiro and P.I. 94549–6. An average of the 7 tests involving F_1 plants of Thatcher hybrids showed 57% fly infestation where Thatcher was completely infested and resistant parents ranged from 0 to 2%. This indicates that resistance genes in the three wheats are not completely dominant. The F_1 plants from crosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 among themselves showed none or very little infestation in the 1948 test.

F_2 Response

The hessian fly infestations of F_2 seedling populations from crosses are given in table 3. Infestations of Ribeiro, P.I. 94549–6, and P.I. 94571–14 in crosses among themselves had low infestations ranging from 0 to 3.1% in 1948. F_2 populations of the same varieties in crosses with Thatcher ranged from 33.7 to 42.2% infestation. The intensity of fly attack in 1951 was somewhat heavier than in 1948 as indicated by an increase of infested plants in parental checks of P.I. 94549–6 and P.I. 94571–14. Selections 6179 and 6232 showed infestation of all plants tested whereas P.I. 94549–6, P.I. 94571–14, W38–6, and Java showed low infestations ranging from 4.9 to 18.3%. The F_2 populations of five crosses involving these parents were rather close in the amount of infestation which varied from 55.6 to 69.3%. There is no apparent explanation for the high infestation in Java × P.I. 94549–6 and Java × W38–6.

Table 1.—Common wheat varieties and geographic origin of those used in hessian fly tests.

Variety	C.I. No.*	P.I. No.†	Country of Origin
Thatcher	10003	———	U.S.A., Minn.
Java	10051	———	U.S.A., Nebr.
Ill. No. 1, W38–6	12061	———	U.S.A., Ind.
Selection 6179‡	———	———	U.S.A., Cal.
Selection 6232‡	———	———	U.S.A., Cal.
Ribeiro Sel.	———	56206–8	Portugal
Unnamed Sel.	———	94549–6	Portugal
Unnamed Sel.	———	94571–14	Greece

* Accession number, Division of Cereal Crops and Diseases, B.P.I.S.A.E.

† Accession number, Division of Plant Exploration and Introduction, B.P.I.S.A.E.

‡ Dawson × Poso[4].

[1] Contribution from the Division of Cereal Crops and Diseases, B.P.I.S.A.E., and the Division of Cereal and Forage Insect Investigations, B.E.P.Q., A.R.A., U.S.D.A.; the Wisconsin Agricultural Experiment Station, Madison, Wis., and the Purdue University Agricultural Experiment Station, Lafayette, Ind. Paper received for publication December 19, 1952.

[2] Agronomist B.P.I.S.A.E. and Entomologist B.E.P.Q., U.S.D.A. respectively.

Table 2.—Hessian fly reaction of F_1 seedling plants from crosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 among themselves and with Thatcher. 1947 and 1948.

Cross and parents	Plants observed		
	Total No.	Infested %	Stunted %
1947			
Thatcher × Ribeiro	38	61	—
Ribeiro × Thatcher	33	73	—
Thatcher × P.I. 94549–6	37	41	—
P.I. 94549–6 × Thatcher	40	63	—
Parents			
Ribeiro	86	1	—
P.I. 94549–6	198	2	—
Thatcher	160	100	—
1948			
Ribeiro × Thatcher	18	33	11
P.I. 94549–6 × Thatcher	6	67	67
P.I. 94571–14 × Thatcher	8	62	0
Ribeiro × P.I. 94571–14	6	0	0
P.I. 94549–6 × Ribeiro	18	0	0
P.I. 94549–6 × P.I. 94571–14	17	6	0
Parents			
Ribeiro	17	0	0
P.I. 94549–6	17	0	0
P.I. 94571–14	18	0	0
Thatcher	16	100	100

Segregation of F_3 Families for Fly Resistance

Segregation of F_3 families for hessian fly reaction is given in table 4 for Ribeiro, P.I. 94549–6, and P.I. 94571–14 in crosses among themselves and in crosses of these with Thatcher. Highest infestation for each of the parents respectively occurred in the 5, 35, and 15 percentage classes. Distribution of F_3 families of Ribeiro × P.I. 94571–14, P.I. 94549–6 × Ribeiro, and P.I. 94549–6 × P.I. 94571–14 was very similar to that of the parents of the crosses. The F_3 families were distributed over a slightly wider range than the parents as might be expected when the number of tests is increased. Nearly all of the families occurred in classes of 0 to 25%. There was only one family each in the 55 and 65 percentage class centers of Ribeiro × P.I. 94571–14 and there was one family each in the 45, 55, and 75 percentage class centers of P.I. 94549–6 × Ribeiro. If a few flowers on F_1 plants of these hybrids had been naturally crossed with Thatcher or some other susceptible variety, these results would have been expected. Fly infestation of the 5 questionable families approximates that found in F_2 populations. A second possible explanation is that of segregation of secondary factors which modify response of the main gene. Since no susceptible F_3 family occurred in these hybrids and since fly responses of the F_1 and F_2 generations approached closely that of the parents, it is concluded that genetic factors for resistance are the same in Ribeiro, P.I. 94549–6, and P.I. 94571–14.

Distribution of F_3 families from Ribeiro, P.I. 94549–6, and P.I. 94571–14 in crosses with Thatcher showed a group of families in classes from 0 to 15%, a second group clustered around the 55% class center, and a third group falling in the 97.5% class center. There was no well-defined break in the distribution curve since families occurred in nearly all classes. However, it was significant that approximately 25% of the families of each cross occurred in the 97.5% class of fly infestation. These families were considered as homozygous susceptible. P values from Chi Square tests show very good fits to expected 3:1 ratios for Ribeiro × Thatcher and P.I. 94549–6 × Thatcher but a poor fit for P.I. 94571–14 × Thatcher. The latter hybrid was deficient in susceptible families.

Table 3.—Hessian fly infestations of F_2 seedlings from crosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 with other varieties of common wheat. 1948 and 1951.

Cross and parents	Plants observed	
	Total No.	Infested %
1948		
Ribeiro × Thatcher	389	33.7
P. I. 94549–6 × Thatcher	382	42.2
P. I. 94571–14 × Thatcher	380	37.3
Ribeiro × P. I. 94571–14	264	0.0
P. I. 94549–6 × Ribeiro	357	0.3
P. I. 94549–6 × P. I. 94571–14	382	3.1
Parents		
Ribeiro	17	0.0
P. I. 94549–6	17	0.0
P. I. 94571–14	18	0.0
Thatcher	16	100.0
1951		
P. I. 94549–6 × Sel. 6179	137	69.3
P. I. 94549–6 × Sel. 6232	73	60.3
P. I. 94571–14 × Sel. 6179	147	63.9
Java × P. I. 94549–6	165	61.8
Java × W38–6	54	55.6
Parents		
P. I. 94549–6	409	18.3
P. I. 94571–14	184	4.9
Selection 6179	196	100.0
Selection 6232	191	100.0
W38–6	225	12.8
Java	451	18.2
Thatcher	139	100.0

Backcrosses

F_1 plants of each of the crosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 with Thatcher were backcrossed to Thatcher. The backcross F_1 plants were grown in the field at Madison, Wis., where there was no selection for hessian fly response. The genetic constitution of F_1 plants was determined by conducting fly tests on the F_2 populations herein referred to as F_2 families. Results of these tests are given in table 5. The distribution showed that F_2 families occurred in most of the classes between 5 and 92.5% while approximately half of the families fell in the 97.5% class. P values from Chi Square tests showed good fits for each backcross to the expected 1:1 ratio. The backcrosses confirmed the one-factor pair difference in Ribeiro × Thatcher and P.I. 94549–6 × Thatcher as shown by segregation of F_3 families. Since the backcross of (P.I. 94571–14 × Thatcher) F_1 × Thatcher showed a one-factor pair difference between the parents, the poor fit to a 3:1 ratio in F_3 family tests is attributed to chance.

It appeared odd that the backcross F_2 families should be distributed over such a wide range of fly classes when only two genetic classes were involved. It was assumed that populations in the 97.5% class were homozygous susceptible but there was a chance that some of those in the 75 to 92.5% classes were homozygous susceptible also. Therefore, it seemed worthwhile to examine the genetic constitution of the backcrosses by sampling in each class of F_2 families below the 97.5% class. Such information was needed in determining limits of the susceptible reaction in other hybrids reported herein. Progeny tests from 20 random plants of Thatcher proved that this variety was homozygous susceptible to hessian fly.

Table 4.—Segregation of F_2 families for hessian fly resistance in crosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 among themselves and with Thatcher. 1948.

Cross and parents	Number of F_2 families or parental rows*			Expected Ratio	P lies between
	Res. and Seg.	Sus.	Total		
Ribeiro × Thatcher	132	42	174	3:1	.80–.70
P.I. 94549–6 × Thatcher	140	47	187	3:1	.98–.95
P.I. 94571–14 × Thatcher	216	45	261	3:1	<.01
Ribeiro × P.I. 94571–14	257	0	257	—	— — — —
P.I. 94549–6 × Ribeiro	339	0	339	—	— — — —
P.I. 94549–6 × P.I. 94571–14	270	0	270	—	— — — —
Parents					
Ribeiro	31	0	31	—	— — — —
P.I. 94549–6	32	0	32	—	— — — —
P.I. 94571–14	56	0	56	—	— — — —
Thatcher	0	150	150	—	— — — —

* Fly infestation of resistant and segregating families ranged from 0 to 95% of the plants, while that of susceptible families ranged from 96 to 100% of the plants.

Table 5.—Segregation of F_2 families for hessian fly response from backcrosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 with Thatcher as the recurrent parent. 1948.

Backcross and Parents	Number of F_2 familes or rows*				Expected Ratio	P lies between
	Res.	Seg.	Sus.	Total		
(Ribeiro × Thatcher) F_1 × Thatcher	0	57	57	114	1:1	1.0
(P. I. 94549–6 × Thatcher) F_1 × Thatcher	0	72	59	131	1:1	.30–.20
(P. I. 94571–14 × Thatcher) F_1 × Thatcher	0	42	51	93	1:1	.50–.30
Parents						
Ribeiro	11	0	0	11	—	— — — —
P. I. 94549–6	12	0	0	12	—	— — — —
P. I. 94571–14	10	0	0	10	—	— — — —
Thatcher	0	0	33	33	—	— — — —

* Families in the 97.5% class were classed as susceptible. Resistant parents did not exceed the 35% class.

The F_3 progenies of 10 random F_2 plants were tested for hessian fly response as a unit basis for those F_2 families tested. Out of 171 F_2 families considered as segregating, 123 were tested in this manner. Results of this test for three backcrosses are given in table 6. The fly classes sampled for (Ribeiro × Thatcher) F_1 × Thatcher ranged from 5 to 85% inclusive. All of the 35 F_2 families tested in this backcross proved to be segregating for fly response as based on the F_3 progenies of 10 F_2 plants. Fifty-one F_2 families were used to sample fly classes ranging from 5 to 92.5% in the hybrid, (P.I. 94549–6 × Thatcher) F_1 × Thatcher, and all segregated except one in the 92.5% class that proved to be homozygous for susceptibility. A similar test of 37 F_2 families for (P.I. 94571–14 × Thatcher) F_1 × Thatcher showed that all of those in the 5 to 75% classes were segregating as based on the F_3 test. One of the two representatives in the 85% class and both representatives in the 92.5% class proved homozygous for susceptibility. Under conditions of this test, it appears that 90% infestation was approximately the line of demarkation between segregating and homozygous susceptible populations. However, this line must remain somewhat indefinite because of the small number of individuals tested (approximately 25) thus introducing a large percentage variation when only one plant is misclassified. In calculating segregation ratios, only those families with infestations of 96 to 100% were classed as susceptible. Low P values obtained for certain of the ratios reported herein may have been caused by the confusion of segregating and susceptible families in the 90 to 95% class.

Also in table 6 is given the total numbers of F_3 lines classed as resistant, segregating, and susceptible from those F_2 families used in sampling the different fly classes. There was a slight tendency for a larger number of F_3 lines to be resistant than susceptible among F_2 families in the lower fly classes and this was reversed in the higher fly classes. The combined segregation for the three backcrosses was determined after combining the resistant and segregating F_3 classes of those F_2 families that showed segregation for fly response. A total of 1159 such plant progenies occurred in the F_3 tests representing 119 segregating F_2 families. The resistant and heterozygous classes included 863 lines while there were 296 in the susceptible class. The P value from a Chi Square test for a 3:1 ratio was .70–.50 which indicated a good fit.

Crosses with Varieties Having Different Genes for Hessian Fly Resistance

It was previously reported (3) that crosses of P.I. 94549–5 and P.I. 94571–14 with W38 showed a two-factor pair difference in segregation of F_3 families. The F_3 family segregation of hessian fly resistance was studied in crosses of Ribeiro, P.I. 94549–6 and P.I. 94571–14 with Selection 6179, Selection 6232, and Java. Results of these tests are given in table 7.

In the F_2 as well as F_3 tests, Selection 6179 with the H_1H_1 gene pair and Selection 6232 with the H_2H_3 gene pair proved completely susceptible to Indiana hessian flies. A majority of check rows of the three resistant parents fell in the 0 to 25 percentage class centers in this test. In crosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 with Selection 6179 and Selection 6232, F_2 families occurred in nearly all fly classes. About 25% of the families were susceptible. P values for Chi Square tests to an expected 3:1 ratio

Table 6.—Classification of plants for hessian fly reaction in the F_2 and F_3 generations from backcrosses to Thatcher, the fly-susceptible parent. 1948 and 1949.

Backcross	F_2 fly class %	F_2 Progenies Tested in F_3 No.	F_2 distribution as based on F_3 lines*			Total number of F_3 lines per class		
			Res.	Seg.	Sus.	Res.	Seg.	Sus.
(Ribeiro × Thatcher) F_1 × Thatcher	5	1	0	1	0	5	5	0
	25	1	0	1	0	1	7	3
	35	5	0	5	0	18	23	9
	45	12	0	12	0	45	51	24
	55	6	0	6	0	15	27	18
	65	2	0	2	0	8	8	4
	75	7	0	7	0	18	32	20
	85	1	0	1	0	1	5	4
(P. I. 94549–6 × Thatcher) F_1 × Thatcher	5	1	0	1	0	3	3	4
	15	4	0	4	0	18	13	9
	25	15	0	15	0	42	69	39
	35	5	0	5	0	14	29	8
	45	7	0	7	0	21	30	19
	55	8	0	8	0	14	25	21
	65	2	0	2	0	4	13	3
	75	7	0	7†	0	12	31	20
	92.5	2	0	1	1	2	4	14
(P. I. 94571–14 × Thatcher) F_1 × Thatcher	5	2	0	2	0	10	7	3
	15	6	0	6	0	8	35	17
	25	12	0	12	0	26	71	23
	35	4	0	4	0	9	21	10
	45	4	0	4	0	5	22	13
	55	1	0	1	0	1	5	4
	65	3	0	3	0	4	15	13
	75	1	0	1	0	1	5	4
	85	2	0	1‡	1	0	2	12
	92.5	2	0	0	2	0	0	20

* Ten single plant progenies tested in the F_3 generation for each line.
† One line represented by 3 plant progenies.
‡ Represented by 4 plant progenies.

showed satisfactory fits in all of the six hybrids although one of the hybrids was somewhat deficient in susceptible families. The tests demonstrated a single gene pair difference in these hybrids. Therefore, it was concluded that the gene pair controlling resistance in Ribeiro, P.I. 94549–6, and P.I. 94571–14 was different than H_1H_1 and H_2H_2 gene pairs.

Java which has the h_4h_4 gene pair for reaction to California hessian flies was crossed with Ribeiro, P.I. 94549–6, P.I. 94571–14, W38–6, and Thatcher. A distribution curve showed a tendency for clusters of F_3 families around the 25 and 65% fly classes in Java × Thatcher. Slightly less than a fourth of the families fell in the 97.5% fly class. The P values from a Chi Square test showed that segregation gave a good fit to a 3:1 ratio indicating a single gene pair difference between the varieties.

Distribution of F_3 families from Java × W38–6 ranged from 0 to the 55% class with about half of them falling in the 15% fly class. Distribution of 47 check rows of the Java parent was very similar except that no check row occurred in the 0% class. Nine check rows of W38–6 fell in the 5 and 15% classes. Since there was no susceptible segregate in 174 F_3 families tested and since the F_3 distribution resembled that of the parents, it was concluded that Java and W38–6 have the same genes governing reaction to Indiana flies. A similar influence of the recessive-acting h_4h_4 gene pair in Java for reaction to California flies was not demonstrated in tests with Indiana flies.

Distribution of F_3 families from crosses of Java with Ribeiro, P.I. 94549–6, and P.I. 94571–14 showed that a major part of the families fell in the 0 to 25% class centers for hessian fly reaction. Only a small part of the families occurred in the 97.5% class. Chi Square tests gave P values showing good fits for 15:1 theoretical ratios in the three crosses. It was concluded that the genes governing fly reaction of Ribeiro, P.I. 94549–6, and P.I. 94571–14 were different than those in Java.

Awns in Relation to Hessian Fly Response

Hessian fly tests of 1947 were conducted on the progenies of F_2 plants which had been classified as awnless or awned. Results of this test are given in table 8. P values from Chi Square tests for awnless and awned classes of F_2 plants of Ribeiro × Thatcher and P.I. 94549–6 × Thatcher showed good fits for a ratio of 3 awnless to 1 awned plants. The F_3 families showed a good fit to the expected 1:2:1 ratio for fly response, except for a deficiency of fly-susceptible families in the awned class of Ribeiro × Thatcher. Families in the resistant and segregating fly classes were combined in relation to the awnless and awned characters to give a 9:3:3:1 ratio. The numbers obtained for Ribeiro × Thatcher were 95:31:32:2 ($P = .10–.05$) and for P.I. 94549–6 × Thatcher were 103:24:32:9 ($P = .50–.30$). P values obtained from Chi Square tests of these segregations showed satisfactory fits to a theoretical dihybrid ratio. This test indicated independence of the genes governing the awnless versus awned condition and those governing fly response in the two crosses.

Stem-rust Resistance and Hessian Fly Response

The F_3 families on which hessian fly tests were conducted in 1947 came from F_2 plants classified for adult stem-rust reaction in the field. The numbers of F_2 plants in resistant or susceptible rust classes indicated that more than one gene was involved in rust resistance. Regarding

Table 7.—F_3 family segregation of hessian fly resistance in crosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 with wheat varieties having different genes for resistance. 1951.

Cross and parents	Number of F_3 families or parental rows*			Expected Ratio	P lies between
	Res. and Seg.	Sus.	Total		
Ribeiro × Sel. 6179 (H_1H_1)	75	18	93	3:1	.30–.20
P. I. 94549–6 × Sel. 6179 (H_1H_1)	137	37	174	3:1	.30–.20
P. I. 94571–14 × Sel. 6179 (H_1H_1)	137	41	178	3:1	.70–.50
Ribeiro × Sel. 6232 (H_2H_2)	37	8	45	3:1	.30–.20
P. I. 94549–6 × Sel. 6232 (H_2H_2)	145	31	176	3:1	.05–.02
P. I. 94571-14 × Sel. 6232 (H_2H_2)	136	44	180	3:1	.90–.80
Java (h_4h_4) × Ribeiro	152	7	159	15:1	.50–.30
Java (h_4h_4) × P. I. 94549–6	174	15	189	15:1	.50–.30
Java (h_4h_4) × P. I. 94571–14	97	4	101	15:1	.50–.30
Java (h_4h_4) × W38–6 (H_3H_3)	174	0	174		
Java (h_4h_4) × Thatcher	117	33	150	3:1	.50–.30
Parents					
Ribeiro	16	0	16		
P. I. 94549–6	18	0	18		
P. I. 94571–14	14	0	14		
Sel. 6179 (H_1H_1)	0	13	13		
Sel. 6232 (H_2H_2)	0	12	12		
W38–6 (H_3H_3)	9	0	9		
Java (h_4h_4)	47	0	47		
Thatcher	1	129	130		

* Resistant and segregating families included those with 0 to 95% infestation; susceptible, those with 96 to 100%.

rust reaction in Ribeiro × Thatcher, there were 64 resistant and 96 susceptible F_2 plants. The fly response of F_3 families from rust-resistant plants segregated 16 resistant, 34 segregating, and 14 susceptible, and the fly response of F_3 families from rust-susceptible plants was 25:52:19 respectively. F_2 plants from P.I. 94549–6 × Thatcher segregated 69 resistant and 99 susceptible to stem rust. The fly response of F_3 families from rust-resistant plants was 12 resistant, 42 segregating, and 15 susceptible and that of F_3 families from rust-susceptible plants was 37:44:18. Since rust inheritance as based on F_2 plants was controlled by more than one genetic factor, the joint segregation for rust reaction and fly response was not clear cut. There was no close relation between rust reaction and hessian fly response.

A second attempt was made to study the relation between stem-rust reaction and fly response in 1948. F_2 plants from crosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 with Thatcher were classified for adult stem-rust reaction in the field. The F_1 plants from backcrosses of the same hybrids to Thatcher were classified also.

The rust reaction of F_2 plants fell into three classes. Stems of resistant plants from Ribeiro × Thatcher showed 0 or a trace of pustules. Intermediate plants averaged about 2% of rust ranging from 1 to 5%. Susceptible plants averaged about 30% of rust ranging from 15 to 60%. The rust classes of F_2 plants from P.I. 94549–6 × Thatcher and P.I. 94571–14 × Thatcher were similar to those of the previous hybrid except the intermediate class averaged 5%. The intermediate and susceptible F_2 rust classes were combined in this study. The resistant and segregating fly classes also were combined since there was overlapping in these classes.

Approximately half of the backcross F_1 plants had 0 or a trace of stem rust, a reaction similar to that of Thatcher which was the recurrent parent. The class with a heavy trace or 1% of rust was combined with the susceptible class in this study. The more susceptible class from backcrosses involving Ribeiro and P.I. 94571–14 averaged about 5% of rust ranging from 2 to 15% whereas that class from the backcross involving P.I. 94549–6 averaged about 10% of rust and ranged from 5 to 15%. Rust severity of this class was more nearly similar to the intermediate than to the susceptible class of F_2 plants mentioned earlier.

Table 8.—F_3 family hessian fly response of seedlings in two crosses previously classified as F_2 plants for the awnless and awned characters. 1947.

Cross and awn classes	Fly response and No. of families				P lies between*
	Res.	Seg.	Sus.	Total	
Ribeiro × Thatcher					
Awnless	33	62	31	126	.98–.95
Awned	8	24	2	34	.02–.01
Total	41	86	33	160	.50–.30
P. I. 94549–6 × Thatcher					
Awnless	38	65	24	127	.30–.20
Awned	11	21	9	41	.90–.80
Total	49	86	33	168	.30–.20

* For expected ratios of 1:2:1.

The joint segregation for stem-rust reaction and hessian fly response is given in table 9. It was evident that stem-rust reaction was governed by more than one genetic factor pair. The crosses and backcrosses segregated for fly response on a monofactorial basis as previously shown. Chi Square tests for the distribution of fly response were made separately for the two rust classes. P values for a 3:1 segregation of fly response of F_3 families in the 3 crosses showed fairly satisfactory fits.

Table 9.—Joint segregation of F_3 family hessian fly response and F_2 plant reaction to stem rust in 3 crosses and similar data for F_2 families and F_1 plants respectively in 3 backcrosses. 1948.

Cross and reaction to stem rust	Fly response and number of families			Expected Ratio	P lies between
	Res. and Seg.	Sus.	Total		
Crosses					
Ribeiro × Thatcher					
Resistant	63	20	83	3:1	.90–.80
Susceptible	68	23	91	3:1	.95–.90
P. I. 94549–6 × Thatcher					
Resistant	10	9	19	3:1	.05–.02
Susceptible	130	38	168	3:1	.50–.30
P. I. 94571–14 × Thatcher					
Resistant	19	5	24	3:1	.70–.50
Susceptible	192	45	237	3:1	.05–.02
Backcrosses*					
(Ribeiro × Thatcher) F_1 × Thatcher					
Resistant	44	36	80	1:1	.50–.30
Susceptible	13	21	34	1:1	.20–.10
(P. I. 94549–6 × Thatcher) F_1 × Thatcher					
Resistant	36	32	68	1:1	.70–.50
Susceptible	34	29	63	1:1	.70–.50
(P. I. 94571–14 × Thatcher) F_1 × Thatcher					
Resistant	25	28	53	1:1	.70–.50
Susceptible	13	27	40	1:1	.05–.02

* Backcross progenies previously shown to consist only of heterozygous and susceptible populations for hessian fly response.

In the backcrosses to Thatcher, Chi Square tests were made for an expected 1:1 ratio for fly response within the two rust classes. P values from the Chi Square tests showed fairly satisfactory fits to expected 1:1 ratios for fly response within the rust classes. This showed independent inheritance of the stem rust and hessian fly characters.

SUMMARY

Inheritance of hessian fly resistance was studied in the greenhouse for the three varieties of common spring wheat Ribeiro, P.I. 94549–6, and P.I. 94571–14. These were crossed with each other, with Thatcher as a susceptible variety, and with tester varieties which carry designated genes for fly response. F_3, F_2 and, in some crosses, the F_1 generations were used in a study of the breeding behavior. Tests in the F_2 and F_3 generations were used to classify F_1 plants of backcrosses.

Crosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 with Thatcher as well as their backcrosses to Thatcher showed a single gene pair difference for hessian fly response. In crosses of Ribeiro, P.I. 94549–6, and P.I. 94571–14 among themselves, no susceptible F_3 family occurred showing that the wheats possess the same genes for fly response.

Selection 6179 with the H_1H_1 gene pair and Selection 6232 with the H_2H_2 gene pair were completely susceptible to Indiana flies. Crosses of Selections 6179 and 6232 with Ribeiro, P.I. 94549–6, and P.I. 94571–14 showed single factor pair differences. Previously published data from crosses of P.I. 94549–5 and P.I. 94571–14 with W38 had given F_3 family ratios of 15 resistant to 1 susceptible. This showed that fly resistance factors of these varieties were different than the H_3H_3 factor in W38. Crosses of Java containing the h_4h_4 gene pair with Ribeiro, P.I. 94549–6, and P.I. 94571–14 gave F_3 family ratios of 15 resistant to 1 susceptible demonstrating a difference in genes that condition fly response.

A cross between Java and W38–6 failed to yield susceptible F_3 families. The h_4h_4 gene pair of Java apparently had no influence on reaction to Indiana flies in this cross.

The symbols H_5H_5 are proposed to designate the incompletely dominant gene pair that condition hessian fly resistance in Ribeiro, P.I. 94549–6, and P.I. 94571–14 and h_5h_5 the allelomorphic gene pair which is present in susceptible Thatcher, Selection 6179, and Selection 6232.

Inheritance of fly response was independent from stem-rust reaction and the awnless versus awned character in crosses and backcrosses involving Thatcher.

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Effect of Bromegrass Variety on Yield and Composition Of a Brome-Alfalfa Mixture[1]

R. R. Kalton and C. P. Wilsie[2]

STRAIN evaluation plays a vital part in all crop breeding programs. To the bromegrass breeder, it presents some rather special problems. The ideal is to evaluate under cultural conditions that closely resemble farm practice. Pure stands, whether planted broadcast or in rows either closely or widely spaced, are easiest to handle and do reflect strain differences. Alternate row seedings of grass and legume likewise may be used for testing and in addition simplify botanical separations. They approach the farm practice of mixed seedings. It may be questionable, however, whether such procedures always yield the type of information actually desired—the predicted relative performance of strains in solid stands in mixture with a legume. Neither can they be expected to result in accurate information on the changing composition of such a mixture over a period of years.

The present investigation was initiated to determine the effect of bromegrass variety on the yield and composition of a brome-alfalfa mixture in a solid seeding, and to relate the results to the problems of strain evaluation. Objectives of this study were threefold: (1) to determine the changing composition of the mixture over several years, as affected by strain of bromegrass and rate of planting of alfalfa; (2) to compare six varieties of bromegrass from an agronomic standpoint; and (3) to evaluate the relationships among the bromegrass and alfalfa portions and the total yields of the mixtures, since the degree of association would have an important bearing on testing of bromegrass strains in a breeding program.

REVIEW OF LITERATURE

Comparisons of agronomic potentialities of different bromegrass strains have been made by a number of investigators (1, 2, 4, 6, 7, 8 and 10). Generally, differences among varieties in forage yield were greatest in pure stands and less when tested in legume mixtures—usually with alfalfa. Varieties and strains of southern origin usually have proved superior to those of northern or Canadian origin in the Corn Belt region and in other areas of similar latitude, under all methods of testing. Farther north, differences between the two types have been less apparent. Extensive tests by Knowles and White (6) at 9 locations in Western Canada showed essentially no differences in hardiness or hay productivity. In all variety studies, higher and more sustained yields were obtained in mixed seedings with a legume than in pure bromegrass stands.

Other differences between the northern and southern types have been observed. Newell and Keim (7) found southern strains to be more vigorous in stand establishment and seedling growth. Elderkin (2) studied stand establishment of Lincoln, a southern type, and Parkland, a northern type, with different rates of seeding alone and in mixture with several varieties of alfalfa. Even though rates were adjusted for germination capacity, Lincoln stands contained three to four times as many seedlings as Parkland five months after planting. Hawk and Welch (4) in greenhouse tests obtained evidence that three southern strains were more tolerant to Pythium root rot than three northern strains. These findings all may have a bearing on effects of bromegrass variety on yield and composition of brome-alfalfa mixtures at subsequent harvests.

Wilsie (10) summarized results of extensive bromegrass-legume experiments at the Iowa Station. In one two-year test total yields and yields of grass portions of the mixture favored southern over northern strains. Yields of legume portions were not affected by brome variety the first year, but in the second year of harvest there was a greater yield of alfalfa with Canadian bromegrass than with several southern strains. On the basis of one year of testing Elderkin (2) found yield of the alfalfa portion of the mixture to vary inversely with yield and aggressiveness of the bromegrass variety. Total yield of the hay mixture was not significantly affected by bromegrass variety. No difference in yield or aggressiveness between northern and southern strains of bromegrass in alfalfa mixtures was observed by Knowles and White (6) in Canada. Percentage of alfalfa in the mixture was similar for a number of strains of varied origin at both first and second cuttings in Michigan (1), except it was higher for Parkland and some strains directly from Russia. Second cuttings were higher in percentage of alfalfa than were first cuttings. It was noted that although certain southern strains were most aggressive they were no lower in percentage of alfalfa in mixtures than less aggressive strains. Thomas *et al.* (8) obtained similar results in tests of Fischer, Martin, Canadian, and Parkland bromegrass in mixture with Ladak alfalfa. In the third year, average percentage of alfalfa in the forage at four locations was 49, 46, 49, and 51%, respectively, for the four varieties. Nothing could be found in the literature pertaining to the year by year effect of different varieties of brome on the composition of brome-alfalfa mixtures.

Problems and results in evaluation of strains of other grass species also have been reported. Hanson *et al.* (3) noted that it was advantageous to test bluegrass strains in association with white clover. In an experiment extending over four years they found that differences in bluegrass strains grown in such associations were reflected in total herbage yields. Weiss and Mukerji (9) compared effectiveness of different planting methods for evaluating orchardgrass strains. They considered performance in broadcast seedings with trefoil or alfalfa as the best measure of true strain potential, and evaluation of pure stands of broadcast seedings the most desirable alternative method of testing.

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Table 1.—Mean yield of total forage and percentage of alfalfa in first cutting of six bromegrass strains sown in mixture with Ranger alfalfa. (12% moisture basis.)

Variety or treatment	1948		1949		1950		1951		Grand Mean
	Tons/ acre	Alfalfa %	Tons/ acre	Altalfa %	Tons/ acre	Alfalfa %	Tons/ acre	Alfalfa %	Tons acre
Lincoln	2.60	73.4	2.36	58.8	2.45	49.2	2.22	50.4	2.41
Fischer	2.54	60.5	2.30	51.6	2.44	37.3	2.15	41.6	2.36
Achenbach	2.40	73.8	2.29	62.2	2.53	41.6	2.22	46.5	2.36
BR43–1	2.48	76.5	2.30	55.1	2.47	40.9	2.17	38.7	2.35
Manchar	2.44	79.5	2.12	64.7	2.17	52.3	1.99	50.1	2.18
Canadian Certified	2.18	74.5	1.94	65.1	2.06	48.8	1.80	51.7	1.99
Mean	2.44	73.0	2.22	59.6	2.35	45.0	2.09	46.5	2.27
4 lbs./acre alfalfa*	2.45	72.8	2.22	58.8	2.37	44.1	2.09	47.1	
8 lbs./acre alfalfa*	2.42	73.3	2.22	60.4	2.33	45.9	2.09	45.9	
Date of harvest	July 1		July 1		July 5		July 6		

* Average of all varieties.

MATERIALS AND METHODS

Six strains of smooth bromegrass, *Bromus inermis* L., were studied. They were: Fischer, Lincoln, Achenbach, Manchar, Canadian Certified, and BR 43–1, the last one being a tall, vigorous hay type synthetic variety resulting from a recombination of eight non-inbred plant selections. Each strain was sown broadcast in mixture with Ranger alfalfa. Seeding rate for bromegrass was 8 pounds per acre. Alfalfa was seeded at two rates, 4 pounds and 8 pounds per acre, with each variety of bromegrass. The 12 treatments were each replicated four times in a randomized complete block design. Plot size was 7 by 33 feet. The test was planted April 29, 1947, at the Agronomy Farm, Ames, Iowa, on a fertile area of Webster silty clay loam with oats as a companion crop. No fertilizer of any kind was applied before seeding or at any time during the investigation.

Two hay cuttings per year were made from 1948 through 1951. Total forage yield was based on a 4½ by 33 foot strip cut through the center of each plot. A 2- to 4-pound sample of forage was taken from the first cutting of each plot immediately after mowing, and was separated into bromegrass and alfalfa portions. The sample was obtained by selecting a handful of forage at each of four random locations along the plot. Green and dry weights of the samples and their portions were used to calculate percentage of bromegrass and alfalfa in the mixture and total yields of the first harvest on a 12% moisture basis. Weeds were not a factor in the separations. Since recovery growth was predominately alfalfa each year, no separations were made on the second cuttings.

RESULTS AND DISCUSSION

First Cutting

Stands of both grass and legume were excellent in all plots the first year after establishment. As shown by the percentages of alfalfa in the first cutting in 1948 (table 1), no apparent difference in the alfalfa portion of the forage resulted from the 4-pound and 8-pound per acre seeding rates. Mean yield of total forage, as an average of all varieties, also was essentially identical for the two rates. This lack of difference in yield and percentage of alfalfa in the first cutting was maintained during the four years of study. For this reason, only average yields and percentages for the two rates appear in table 1.

On the basis of total forage yields, Lincoln, Fischer, Achenbach, and BR 43–1 were similar and highest in yield each year. Manchar was as high the first year but definitely lower in succeeding years. Canadian Certified, a northern type, was poorest in yield every year. It averaged 0.38 tons per acre below the average of the southern strains during the four-year period. Analyses of variance indicated that these differences in mean yield were statistically significant each year.

Average percentages of alfalfa in the forage for each year and variety also are found in table 1. Manchar had the highest and Fischer the lowest alfalfa percentages the first year. Percentages of alfalfa were intermediate and similar for the other strains, but closer in value to Manchar. The percentage of alfalfa in the mixture dropped from the first to the second year and from the second to the third year. No further decline was evident between the third and fourth year, and some varieties actually showed a slightly higher percentage in 1951 than in 1950. As an average for the last two years, Fischer and BR 43–1 were lowest, Achenbach intermediate, and the other three about equally high in percentage of alfalfa. Thus, most strains held their rank with respect to alfalfa content during the four years even though a marked decrease in average percentage occurred. BR 43–1 was somewhat of an exception, being second high the first and lowest the last year. In general, these results indicate little or no effect of bromegrass variety *per se* on alfalfa stand depletion.

Additional information was obtained by variance analyses of the brome and alfalfa portions of the mixtures. Differences in mean yield among varieties were significant at the 1% level for the alfalfa portions in the first year only, and for each of the first three years for the brome portions. An indication of a variety by rate interaction for both portion analyses was observed in 1949. Lack of any marked

Table 2.—Correlations of bromegrass and alfalfa portions of forage with total yields from first cutting of six bromegrass strains planted in mixture with Ranger alfalfa.

Items correlated	Year			
	1948	1949	1950	1951
Total yield and:				
Yield of alfalfa portion	0.41	0.31	0.11	0.56
Yield of brome portion	0.44	0.68*	0.81†	0.73†

* $P<0.05$.
† $P<0.01$ (10 degrees of freedom).

Table 3.—F test for heterogeneity of regression coefficients of percentage of alfalfa on year for six bromegrass strains.

Source of variation	D. F.	Symbol	Sum of squares	Mean square	F
Common slope	1	γ	2,660.21		
Differences among slopes	5	$\beta-\gamma$	104.86	20.97	0.53
Individual slopes	6	β	2,765.07		
Deviations from individual slopes	12	$\alpha-\beta$	471.96	39.33	
Total within strains	18	α	3,237.03		

effect of planting rate of alfalfa on either portion of the mixtures was evident, however, in the very low variances that were obtained for rates in all years.

Considering all analyses, it would appear that differences in yield among varieties, in the brome portions of the mixtures, were usually more influential in determining total yield performance than were varietal differences in alfalfa portions. This was especially evident in the 1949 and 1950 analyses. For further information, correlation coefficients expressing relationships between the brome and alfalfa portions and total yields of the strains are given in table 2. In all cases the degree of association was higher for the brome portions than for the alfalfa portions.

The difference in degree was only slight the first year but substantial in subsequent years. This further indicates the important influence of bromegrass variety on total yields even when the proportion of bromegrass on a weight basis constitutes about half or less than half of the total forage. It emphasizes also the desirability of continuing experiments for several years to obtain the greatest amount of information.

Second Cutting

Discussion thus far has centered on yield and composition of the first harvest each year. Second cutting yields were taken in all years during the middle of August. In the first two years aftermath growth was estimated to contain from 80 to 90% alfalfa in most plots. Consequently, no separations were made and only green weights recorded. Analyses of variance of green weights indicated no significant differences in mean yield among varieties or rates either year. Dry weight determinations were made in 1950 but no differences were found. The last year (1951) was favorable for forage recovery, due to ample rainfall and cool temperatures in July and early August. Separations were made on a few plots and a range in percentage of alfalfa from about 43 to 87% found, but no significant differences in green weight yields due to variety or rate were noted. These results seem to indicate that yields of second cuttings offered little opportunity for detecting bromegrass variety differences in forage yield potentialities.

Regression Analysis

Since a major objective of the experiment was to determine if bromegrass varieties differed with respect to their ability to compete with alfalfa, coefficients of the regression of percentage of alfalfa on year of harvest were computed for all brome varieties. Using a technique outlined by Kempthorne (5) an F test was made for heterogeneity of the regression coefficients. The method and results appear in table 3.

Since the mean square for differences among slopes was less than that for deviations from individual slopes, it may be concluded that the rate of stand depletion of alfalfa during the four years was similar for all varieties of bromegrass in this test. Individual regression coefficients (b's) for percentage on year were: —7.1, —7.9, —8.5, —10.1, —10.2, and —12.8% for Fischer, Lincoln, Canadian, Manchar, Achenbach and BR 43–1, respectively. These results indicate that in this experiment the southern varieties were no more competitive with alfalfa than the northern varieties. Varietal differences in initial stand establishment, as pointed out by Wilsie (10), seem to be the primary factor in determining mixture composition over a period of years, not a bromegrass variety differential in rate of stand depletion of alfalfa.

SUMMARY

1. Six varieties of bromegrass were sown broadcast with Ranger alfalfa and evaluated for forage yield and mixture composition for a four-year period. Alfalfa was seeded at two rates (4 and 8 pounds per acre) in mixtures but no differences in yield or composition due to rate were found.

2. Total forage yields of first cuttings differed significantly among varieties each year. Lincoln, Fischer, Achenbach, and BR 43–1 were equally high, Manchar intermediate, and Canadian Certified low in yield for the four-year period. No differences among varieties in total yield were evident in second cuttings in any year.

3. Average percentages of alfalfa in the first forage harvest for all varieties were 73.0, 59.6, 45.0 and 46.5% for the first, second, third, and fourth year, respectively. There was no indication that the bromegrass varieties in this experiment differed with respect to degree of competition with alfalfa.

4. Comparisons of bromegrass and alfalfa portions of first cutting forage with the total yield indicated that differences in bromegrass portions were the more important of the two in determining differences in total yield. From a breeding standpoint all results give evidence that total first cutting forage yields of brome-alfalfa mixtures provide a fairly reliable indication of bromegrass variety potential for hay production.

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Effect of Selection Upon Bulk Hybrid Barley Populations[1]

R. E. Atkins[2]

PLANT breeders are continually faced with the problem of how to best evaluate available breeding material. Numerous studies have been conducted with the self-pollinated crops relative to systems of hybridization and selection. Evidence favoring the pedigree method of handling segregating populations has been reported by several workers. Similarly, studies that substantiate the value of the bulk method of breeding have been presented. Modifications and refinements of both methods have been proposed and used by some workers. Many plant breeders use both systems or a combination of them at various times depending upon funds and help available.

A rod row yield test of the bulk F_2 generation of a group of barley hybrids was grown at Ames, Iowa in 1946. Striking segregation for a number of characters was evident in this material. Wide differences in plant vigor, size and filling of heads and in degree of infection by head blight organisms were particularly apparent. Barley scab was exceptionally heavy and head blight caused by *Helminthosporium sativum* also was severe. Spikes differed widely in the number of sterile or poorly filled basal spikelets and in filling of spikelets at the tip of the spike. The purpose of this investigation was to determine the magnitude and direction of shifts in these segregating bulk populations from continued selection through several generations for vigorous plants with large, well-filled, disease free heads.

REVIEW OF LITERATURE

Investigations relative to the systems of hybridization and selection used in small grain improvement have been reviewed by Atkins and Murphy (1) and by Taylor (5). The essential features and procedures of both the bulk and pedigree methods of breeding have been outlined by Hayes and Immer (3) and by Love (4). Advantages cited for the pedigree system would include the possibility of allowing a joint attack on breeding and inheritance problems through spaced planting with the resultant detailed notes obtained, and secondly that a somewhat shorter time usually is required in the production of an improved variety. The bulk system may be considered to have the advantage of requiring less detailed work in early segregating generations which permits the growing of a larger sample of the segregating population. A larger number of crosses therefore may be evaluated in the early generations at a lesser cost.

Harrington (2) proposed a combination or modification of the bulk and pedigree systems of breeding, which he termed the mass-pedigree method. He suggested growing segregating populations in bulk until a season favorable for efficient selection occurred. Selections then would be made on a head rather than a plant basis and grown in accordance with the pedigree system in succeeding generations. The system of selection utilized in the studies reported herein parallels Harrington's system in that selections were made during favorable seasons on a head basis. It differs in that repeated head selection was practiced through three generations and the resultant population then bulked for evaluation without use of the pedigree procedure.

EXPERIMENTAL PROCEDURE

Selections were made at maturity from the eight border rows of 11 F_2 bulk hybrid barley populations at Ames during the 1946 season. A total of 160 to 180 heads of each cross were selected from the four replicates, threshed in bulk and the seed used to plant the selected F_3 plots in 1947. No selection was practiced in the center rows of the bulk F_2, and this seed was used to plant the bulk F_3 in 1947. The bulk and selected material was grown at Kanawha, Iowa, in 1947 in a split-plot experiment, in three rod-row plots with three replicates. Selection was practiced as in 1946 in the border rows of the selected plots to obtain seed for planting the selected F_4 in 1948. The experiment was grown at Ames in 1948 using the same design and procedure as in 1947.

Seven crosses were selected for evaluating the performance of the three selected generations in comparison with the corresponding bulk generations during the 1949 season. This experiment was

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[2] Associate Professor of Farm Crops. Indebtedness is expressed to Dr. I. J. Johnson, Professor in Charge of Farm Crops, Iowa Agricultural Experiment Station and to Dr. D. D. Morey, Associate Agronomist, Florida Agricultural Experiment Station, Gainesville, Fla., formerly Research Associate, Iowa Agricultural Experiment Station, who initiated the investigation and made the selections during the 1946 and 1947 seasons.

Table 1.—Mean yield, heading date, maturity date, lodging and plant height of bulk and selected generations of seven barley crosses, Ames, Iowa, 1949 and 1950.

Year	Character	Generation						
		Bulk				Selected		
		F_2	F_3	F_4	F_5	F_3	F_4	F_5
1949								
	Yield, (Bu./Acre)	38.7	33.2	33.0	36.5	38.7	37.2	36.1
	Date headed, (June)	7.4	6.4	6.6	6.1	7.1	7.7	9.0
	Date mature, (July)	2.7	2.9	3.3	3.0	3.0	2.7	3.6
	Lodging, (Percent)	42.0	28.1	32.7	29.6	29.0	34.0	21.0
	Plant height, (Inches)	32.7	32.1	32.3	32.7	33.3	33.3	34.0
1950		F_3	F_4	F_5	F_6	F_4	F_5	F_6
	Yield, (Bu./Acre)	47.5	45.2	46.2	46.6	47.2	47.6	46.3
	Date headed, (June)	17.1	15.9	16.1	16.0	16.9	16.7	17.9
	Date mature, (July)	15.9	16.3	16.4	16.3	16.1	16.1	16.1
	Lodging, (Percent)	6.0	6.7	3.6	6.6	5.7	3.6	4.7
	Plant height, (Inches)	38.3	38.4	38.7	38.1	39.7	39.3	39.7

Bushels for significance between generations:
1949 5% level = 3.4 1950 5% level = 3.2
1949 1% level = 4.6 1950 1% level = 4.3

grown at Ames as were the succeeding experiments in 1950 and 1951. Parentage of the crosses chosen was as follows: Coast × Mars, Wisconsin 38–Chevron × Coast, Bolivia–Chevron × Glabron–Peatland, C.I. 1613 × Velvet–Peatland, Manchuria × Chevron, C.I. 5075 × Wisconsin 38–Chevron, and Manchuria × Mars. The selected F_3, F_4 and F_5 and the bulk F_2, F_3, F_4 and F_5 generations of each cross were grown together with seven of the parental varieties in a split-plot design. Crosses were used as whole-plots and the different generations as sub-plots. The seven parental varieties were grown as a group in one whole-plot in each replicate, but were not included in the analysis. Five replicates of single half-rod row plots were grown with the variety Mars planted in alternate rows to provide uniform competition. Grain yield was obtained and field notes were taken on date of heading, date of maturity, plant height and lodging.

The 1949 season was unusually hot and dry in May and June. Some crosses prematurely ripened and early maturing lines undoubtedly were favored while late maturing lines may not have expressed their true yielding capacity. The experiment, therefore, was repeated in 1950. Because sufficient remnant seed of the selected generations was not available for an exact duplication of the 1949 test the seed harvested in 1949 was planted in the 1950 experiment. All populations thus were advanced one generation. The field design in 1950 and the notes taken were as described for the 1949 experiment, except that single rod-row plots were used.

A trend toward later heading, later maturing and taller types in the selected populations was indicated in the 1947 and 1948 tests. Space planted populations of 300 plants each of the bulk F_5 and selected F_5 of each cross were grown in 1949 to provide material for measuring the magnitude of such shifts. Forty-five plants were selected at random from both the bulk and selected F_5 plantings of each of eight crosses. F_6 seed from a single head of each of the 720 plants was planted in a completely randomized experiment of three foot rows at Ames in 1950. Date of heading, date of maturity and plant height were taken on each head row.

The final phase consisted of an evaluation of the variance for yield within groups of bulk lines and selected lines from the 1950 head rows. The F_7 generation of 20 bulk and 20 selected lines from four crosses was grown in 1951. A split-plot design was used with crosses as whole-plots and bulk versus selected lines as the sub-plots. The bulk F_3, F_5, F_4 and F_5 generations of each cross and either the 20 selected or 20 bulk lines were assigned at random within each sub-plot. Two replicates of single half-rod row plots were grown with the variety Plains in alternate rows to provide uniform competition.

EXPERIMENTAL RESULTS

Yield and other agronomic data obtained on the seven crosses in 1949 and 1950 are presented in table 1. An average of the comparable F_4 through F_6 selected and bulk generations in 1950 showed a yield gain of 1.0 bushel per acre for the selected material. Average yields of the F_3 through F_5 generations in 1949 were 3.1 bushels greater for the selected generations. An increase of 1.9 bushels per acre also was obtained in favor of the selected F_4 in comparison with the bulk F_4 in the 1948 experiment. Yield data were not obtained on the bulk and selected F_3 generation grown in 1947. Although the yield differences exceeded the 5% level only in 1949, they were consistently in favor of the selected generations in all seasons.

In both 1949 and 1950 the greatest increase in yield was apparent in the first selection from the bulk population. A smaller gain was indicated from the second cycle of selection and no gain was obtained from the third cycle of selection. Because the 1949 season was not favorable for late maturing types it was likely that at least part of the smaller advantage in the selected F_3 might have been due to premature ripening and poor filling of the grain in the late maturing selections. In the more favorable 1950 season, however, the comparative yield differences of the bulk and selected generations were very similar to the 1949 data. The greater effectiveness of selection in the first cycle may be due in part to the greater degree of genetic diversity present in the original hybrid population.

Analyses of variance showed significant differences in yield among the bulk generations and between the bulk and selected generations in 1949 but differences among the selected generations did not reach the 5% level of probability. In 1950 neither the differences among bulk generations, selected generations nor the bulk versus the selected generations exceeded the 5% level of probability. Differences between means of bulk and selected populations were in favor of the selected group as in 1949, however.

Variance analyses were not computed for the other characters presented in table 1. A shift toward later heading and slightly taller types in successive generations of the selected populations was indicated, however. No appreciable change was noted in maturity of the selected populations when compared to the corresponding bulk generations. In addition to the data given in table 1, the 1948

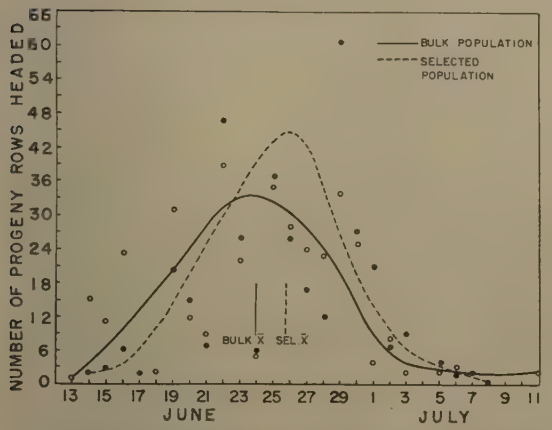

FIG. 1.—Frequency distribution of heading date for bulk and selected F_6 populations of eight barley crosses, Ames, 1950. Bulk population values represented by circles and selected population by dots.

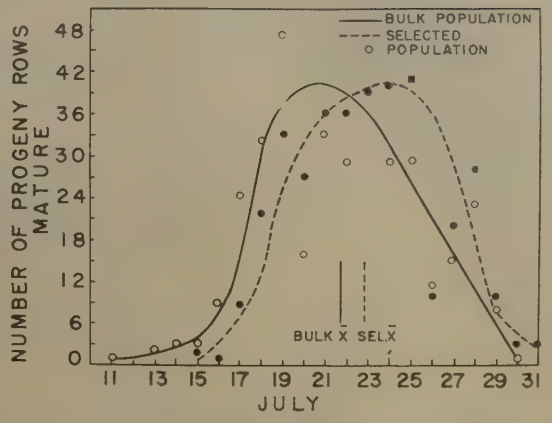

FIG. 2.—Frequency distribution of maturity date for bulk and selected F_6 populations of eight barley crosses, Ames, 1950. Bulk population values represented by circles and selected population by dots.

experiment with bulk and selected F_4 generations showed the selected generations to average one day later in heading, one inch taller in height but they did not differ from the corresponding bulk material in average date of maturity. No trend toward stiffer strawed types was apparent in the selected populations.

A frequency distribution of heading dates of the bulk and selected F_6 populations of eight barley crosses grown in 1950 is given in figure 1. Similar distributions for date of maturity and plant height are presented in figures 2 and 3, respectively. A marked shift toward later heading types in the selected population is evident in figure 1. A less pronounced, but definite shift toward later maturing and taller types among the selected group is shown in figures 2 and 3, respectively. The greatest shift in date of heading, followed by lesser shifts in plant height and maturity date is in agreement with data obtained from rod row trials in previous years.

The variability for yield in the F_7 generation of 20 selected and 20 bulk lines from each of four crosses grown in 1951 was analyzed. Lines from the selected populations averaged significantly higher in yield than lines from bulk populations. Greater variation in yield among bulk lines was indicated for two crosses, while greater variation among selected lines was apparent in one cross. No difference in yield variability of the bulk and selected lines was obtained in the remaining cross. Various bulk generation check plots did not differ significantly in yield in 1951.

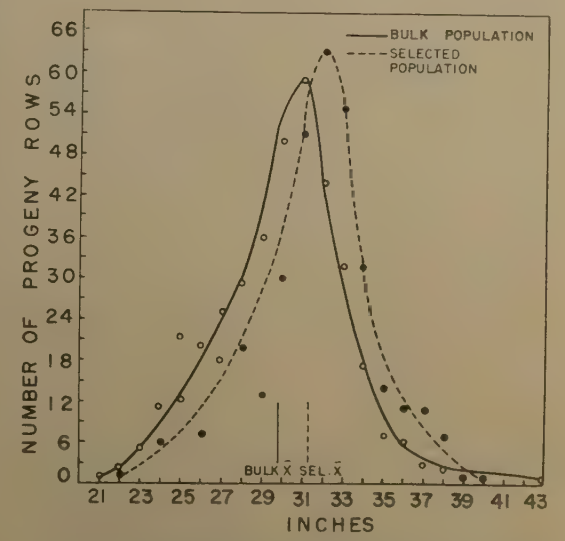

FIG. 3.—Frequency distribution of plant height for bulk and selected F_6 populations of eight barley crosses, Ames, 1950. Bulk population values represented by circles and selected populations by dots.

DISCUSSION

Selection within segregating hybrid populations should be most effective for characters that can be accurately measured and whose inheritance is not complex. Very effective selection for rust resistant types in oats has been accomplished by a number of plant breeders. Good sources of resistance to the rusts are available and clear cut classification of resistance and susceptibility in segregating populations is possible. For certain other diseases in small grains and for more complex agronomic characteristics, such as yield, definite visual criteria for selection are not as apparent. Characters toward which selection was directed in this study undoubtedly would fall in the latter classification.

Yielding ability in barley, and other crops, represents the combined expression of a number of plant characteristics. Plant vigor, tillering capacity, head size and ability to fill must be considered integral parts of grain yield. Among high yielding varieties a few small headed types may be found, but they are in a distinct minority. Degree of head blight from scab or other pathogens probably should not be considered a direct component of yield, but most certainly would be an indirect factor having considerable effect.

Shifts of varying magnitude were occasioned by the methods of selection used herein. Selection was directed toward criteria that might be expected to have greatest

effect on yield. Limited progress was made in obtaining higher yielding populations, while shifts of equivalent magnitude were obtained for several other characters. Selection was not directed toward heading date, maturity or plant height in the segregating populations, but shifts resulted toward taller, later types. However, selections were made when all heads in the segregating plots had reached maturity, which apparently favored taller, later types.

A reduction in variability for yield might be expected in the selected populations as compared with corresponding bulk generations. An examination of the variance for selected and bulk F_7 lines of four crosses grown in 1951 partially substantiates this expectation though not as conclusively as might be anticipated.

SUMMARY AND CONCLUSIONS

Continued selection in F_2, F_3 and F_4 generations of 11 bulk hybrid barley populations for vigorous plants with large, well-filled, disease free heads was practiced during the period 1946–1948. Evaluation of the selected populations of eight of the crosses for yield, heading date, maturity date, plant height and lodging resistance in comparison with their respective bulk populations was accomplished during the 1949–1951 seasons.

Selected populations were somewhat higher yielding than corresponding bulk populations in all but a few instances. Yield increases, however, exceeded the 5% level of probability only in 1949 and 1951. Selection, as practiced herein was not effective in isolating appreciably higher yielding lines.

Segregates from selected populations were approximately two days later in heading, one day later in maturity and 1½ inches taller than corresponding bulk populations. Lodging resistance of selected lines did not differ from non-selected populations.

Variability for yield among 20 bulk and 20 selected F_7 lines from four crosses grown in 1951 was measured. Increased yield in the selected lines as compared to the bulk lines exceeded the 1% level of probability. Greater variation in yield among bulk lines was indicated for two crosses while greater variation among selected lines was apparent in one cross. The fourth cross showed no difference in variability for yield between the bulk and selected populations.

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Chemical Defoliation of Cotton I. Bottom Leaf Defoliation[1]

Lamar C. Brown[2]

CHEMICAL defoliation of cotton has proved to be advantageous. In defoliated cotton the increased exposure to sunlight plus the drying action of air movement tends to cause mature bolls to open faster, reduce boll rots, and retard fiber and seed deterioration. In addition, defoliation usually makes either mechanical or hand harvesting easier. These and other benefits have been outlined in some detail (2, 4).

Regardless of these benefits, many difficulties are encountered in adapting chemical defoliation to fit specific needs and plant types found in some areas of the irrigated Southwest. Cotton varieties utilized in most desert sections of the irrigated Southwest are indeterminate in growth habit. Consequently, plants grow tall, rank, and exhibit a heavy canopy of foliage. Under these conditions the damp environment sometimes found near the bottom of such plants will favor boll rot and delay boll opening. Harvesting will be delayed, grade lowered, and yields decreased.

Other problems are encountered during the regular defoliation season. Complete coverage of the foliage is usually stressed as a requisite for good defoliation regardless of the method of application. When plants are closely spaced and reach a height of 6 or more feet, defoliants do not always reach the lower leaves resulting in the need for a second application at additional expense to the grower.

Unfortunately, defoliation of the entire plant cannot always be used to combat early damage from boll rot. Premature, or early season chemical defoliation can cause injury to the fiber quality, reduction in yields, and other detrimental factors. The possibility of removing the lower leaves as a method to combat boll rots and delayed boll opening has been suggested (2, 3, 5); however, the feasibility of bottom defoliation would depend on how this process might affect the cotton plant. Other problems would be encountered such as: means and methods of application, rates per acre, and the timing of the application.

In order to investigate the general effects of bottom defoliation on the cotton plant several experiments were conducted during 1951 and 1952. The data reported herein

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[2] Plant physiologist, U.S.D.A., B.P.I.S.A.E., U. S. Field Station, Sacaton, Ariz.

are concerned primarily with the general effects of bottom defoliation on the cotton plant rather than with means and methods of application.

METHODS AND MATERIALS

The more intensive studies were conducted at the U. S. Field Station, Sacaton, Ariz., and the so-called general experiments were conducted at selected locations throughout the state of Arizona.

Plots other than those for demonstration purposes were arranged in split plot designs with defoliants as main plots and treatments as sub-plots. Plot size varied from 1/30 acre in some experiments to 1/3 acre in others.

Defoliants were applied with a hand-duster or hand-spray in the small plot experiments. In the large plot experiments the majority of the defoliants were applied with a Hahn Hi-Boy high clearance rig. This machine could easily be used in cotton that reached a height of 6 or 7 feet. The spray was directed toward the lower part of the plants by two low-placed nozzles on each side of the row. An adjustable boom allowed the spray to be directed toward the lower part of the plants at all times. In general, the defoliants were applied to the commercial variety A44, only when the bottom bolls were essentially mature (35+ days).

A list of the commercial defoliants and rates in the study is included in table 1. Several other equally efficient defoliants, including dusts, were used in these experiments and the choice of defoliants mentioned in this paper does not constitute a recommendation of these over any other equally efficient cotton defoliant.

Fiber analyses of cotton sample collected from the experimental plots were made at the conclusion of each experiment. Such analyses provided the basis for a determination of the effects of defoliation on the fiber properties of the cotton plant.

Table 1.—Defoliants and rates.

Chemical	Active Ingredient (Pct.)	Trade Names*	Acre rates used in these studies
Sodium chlorate (with sodium pentaborate)	40	Shed-A-Leaf	2– 9 lbs.
Sodium ethyl xanthate	85	S.E.X.	3–10 lbs.
Monosodium cyanamide	85	AERO Sodium Cyanamid, X-5	5–18 lbs.

* Trade names are used only for the purpose of identification.

RESULTS

The data from studies primarily concerned with boll rots are presented in table 2. Plants were selected at random from control plots which had not received any defoliant, and from plots that had the bottom leaves defoliated. Counts were made on several of the plants in each plot as to the number of healthy bolls and the number of rotted bolls. These counts were made 14 days after application of the defoliants. It can be seen from table 2 that boll rots were significantly reduced by bottom defoliation.

Other experiments were designed to study the rate of boll opening in bottom defoliated plots. Counts of the number of open bolls on bottom defoliated and undefoliated plots began on Sept. 5, 1952, ten days after the application of defoliants, and continued until Sept. 25. A significant increase in the rate of boll opening was found associated with bottom defoliation. These data are presented in table 3. Further evidence may be noted in figure 1. The bottom defoliated plant on the left has several open bolls and is relatively free from boll rots. The control plant on the far right has but a few open bolls and many bolls are rotted.

Table 2.—Percentage of boll rot found in bottom defoliated and undefoliated plots.

Defoliant	Mean	
	Undefoliated	Defoliated
X-5	23.7	7.3
Shed-A-Leaf	23.3	6.7
S.E.X.	19.7	5.7
	22.2	6.6**

** Significant at the 1% level.

Table 3.—Number of open bolls in 30 feet of row of bottom defoliated and undefoliated plots.

Date of counts	X-5		S.E.X.		Shed-A-Leaf	
	B. Def.	Un-def.	B. Def.	Un-def.	B. Def.	Un-def.
Sept. 5	33	15	22	7	21	5
Sept. 15	71	37	78	43	69	33
Sept. 25	118	84	127	77	123	81

Table 4.—Comparison of defoliation percentages between control plots and bottom defoliated plots after defoliants were applied so as to completely cover the entire plant. Defoliation percentages indicate the percentage of foliage removed from the plants in each plot.

Defoliant	Mean	
	B*	C†
X-5	85.7	69.7
Shed-A-Leaf	87.3	70.0
S.E.X.	83.7	69.3
	85.6	69.7**

** Significant at the 1% level.
* Denotes plots in which bottom leaves had been removed prior to complete defoliation.
† Denotes control plots.

FIG. 1.—Bottom defoliated and undefoliated rows. The plants on the left have several open bolls and are relatively free from boll rots. The control plants on the right have but a few open bolls and many bolls are rotted.

Additional experiments were concerned with the effect of bottom defoliation on late season defoliation efficiency. Defoliants were applied so as to completely cover all remaining leaves on the plants in plots which had previously been bottom defoliated. Defoliants were also applied to adjacent undefoliated plots. Defoliation percentages were obtained by leaf counts before and after defoliation. The resultant data, expressed in terms of percent defoliation, are shown in table 4. The increase in efficiency of defoliation in the bottom defoliated plots can be noted in these data.

In several experiments the effects of bottom defoliation on weeds and grass were studied. The majority of the weeds and grass in the bottom defoliated plots were either killed or retarded in growth as a result of bottom defoliation. This would be of considerable importance in eliminating weeds and grass which could interfere with picking efficiency later in the season.

DISCUSSION

The amount of boll rot that can be found in irrigated cotton varies from year to year, but the threat is always present. Examination of the data in table 2 shows that the percentage of boll rot was greatly reduced in the plots that had been bottom defoliated. Another advantage is brought out by results shown in table 3. A delay in the rate of boll opening is often found when plants grow tall, rank, and exhibit a heavy canopy of foliage. However, with the lower leaves removed the rate of boll opening is much faster, sometimes allowing the grower to make a first picking as much as two weeks earlier than could be expected without bottom defoliation. Data in table 4 indicate another advantage. In cotton that is 6 feet in height the defoliant does not always reach the lower leaves, necessitating a second application at additional cost to the owner. With the lower leaves removed, the final application should be highly efficient. Another advantage is the use of bottom defoliation as a method of grass and weed control. It has been noted that the greater percentage of the grass and weeds in bottom defoliated plots was either killed or retarded in growth. This may suggest the possibility of using this practice as a substitute for late cultivation.

Most of the bottom leaves are essentially mature at an early date and contribute little toward the development of the top crop. Therefore, bottom defoliation *per se* should not be detrimental to the immature bolls found in the upper half of the plant. Since bottom defoliation is done at a time when plant activity is high and the defoliants are applied only to mature leaves, nearly complete removal of these lower leaves may be expected with good placement of defoliants at effective rates. The rates may vary with the defoliant used but, in general, the higher rates as outlined in table 1 were found to be the most efficient.

All types of cotton are not suitable for bottom defoliation. The advantages are best utilized in cotton that is tall, rank, and exhibits a heavy canopy of foliage. A factor of prime importance is the direction of the spray or dust pattern. It should be directed so that only the lower leaves are covered with the defoliant. A spray or dust pattern that is directed toward the top of the plants may result in excessive square shedding or possible damage to the lint or fiber properties.

The maturity of these lower bolls is a factor of great importance. It is recommended that the lower bolls be at least 35 days of age, i.e., 35 days from flowering. Results of fiber analyses showed that there was no damage to the lint or reduction in fiber quality as a result of bottom defoliation if the defoliants are applied at this age. Mature bolls usually open faster in the drier environment provided by bottom defoliation. It should be kept in mind that defoliation should not be used as an instrument for speeding boll maturity. Such practice will produce immature seed and fiber.

There was no appreciable difference between the defoliants used in this study, although more accurate placement could be obtained with a spray defoliant. A dust tends to billow up in the turbulence created by a tractor and the dust blower. This may result in complete coverage of rather tall plants, which would defeat the purpose of bottom defoliation, or make it impossible to defoliate only the lower leaves.

The problem of regrowth should be considered. Very little regrowth was evident in these studies. However, regrowth may begin as early as two to three weeks after the lower leaves are removed. Results with growth inhibitors (1) indicate that it may be possible to mix certain growth inhibitors with the defoliants and thus cause a reduction in the amount of second growth. At present, the overall effects of these growth regulators have not been determined and they cannot be recommended.

SUMMARY

1. Bottom defoliation appears to be beneficial in the following respects: it reduces the amount of boll rots; it increases the rate of boll opening; grass and weeds are either killed or retarded in growth; and better overall defoliation efficiency is obtained at the end of the season.

2. Several precautions should be taken. The spray pattern should be directed only toward the bottom of the plants in order to avoid excessive square shedding and possible damage to the lint in the immature bolls. Effective rates are those used for complete defoliation.

3. There is no established time for bottom defoliation. However, it is recommended that the lower bolls be at least 35 days of age, i.e., 35 days from flowering. In Arizona the lower bolls usually attain this age during the months of August and/or September.

4. Dust defoliants are not recommended for use in bottom defoliation practices at this time.

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Registration of Improved Wheat Varieties XX[1]

Fred N. Briggs[2]

SIOUX (REG. NO. 347)

SIOUX (C.I. 12142) was developed by the Nebraska Agricultural Experiment Station and the Division of Cereal Crops and Diseases, U.S.D.A. from a cross between Cheyenne and Turkey 1062. The cross was made in 1935 and the selection which was named Sioux was made in 1939. Two important characters of Sioux are its bunt resistance and winterhardiness in which it appears to be equal to Nebred. In Nebraska Experiment Station's Outstate Tests this variety has been approximately equal to Cheyenne and Nebred and has consistently outyielded Turkey and Pawnee. Sioux is being distributed in central, south-central, southwestern, and western Nebraska but is not recommended for counties east of U. S. Highway 81.

[1] Registered under a cooperative agreement between the B.P.I.S.A.E., ARA, U.S.D.A. and the American Society of Agronomy. Received for publication May 1, 1953.

[2] Fred N. Briggs, Dean–Agriculture, University of California, Davis, California. Member of Committee on Varietal Standardization and Registration of the Society of Agronomy charged with the registration of wheat varieties.

Registration of Flax Varieties VI[1]

J. O. Culbertson[2]

NEW flax varieties have been described in issues of the Agronomy Journal as follows: Biwing and Redson, September 1943; Crystal and Royal, May 1944; Arrow, Renew, and Koto, August 1945; Dakota and Minerva, November 1949; and Sheyenne and Redwood, March 1952.

MARINE, REG. NO. 12

Marine (C.I. 1135)[3] was developed at the North Dakota Agricultural Experiment Station in cooperation with the Division of Cereal Crops and Diseases, U. S. Dept. of Agriculture. It was selected in 1944 as an F_4 line from a cross of C.I. 975 × Sheyenne made by H. H. Flor in 1942.

In 1952 approximately 7,500 acres of registered and certified Marine were grown in North Dakota, Minnesota, and South Dakota. This should provide seed for sowing 150,000 acres in 1953.

Marine is satisfactory in resistance to wilt, *Fusarium oxysporum* Schlecht. f. *lini* (Bolley) Snyder & Hansen, is as tolerant as any commercial variety to pasmo, *Mycosphaerella linorum* (Wr.) Garcia Rada, and has the Ottawa 770B gene for rust reaction. This gene conditions immunity to all known North American races of flax rust, *Melampsora lini* (Pers.) Lév. The flowers of Marine are blue, the seeds small to midsize, and a chocolate brown in color. It is an early variety, maturing only a day or two later than Sheyenne or Redwing. Marine is similar to Sheyenne in height and plant type.

As an average of 34 trials in the Uniform Regional Flax nursery, Marine has averaged just slightly lower than Bison in oil percentage, and a little higher in oil quality (iodine number) than Redwing.

Relative yields of Marine, Sheyenne, Redwood, Rocket, and B5128 in terms of percentage of Bison, the check variety, at six locations in the North Central area are shown in table 1. Although the Uniform Regional Flax Nursery trials are sown early, favoring the later maturing varieties, Marine has made a good yield record in the North Central area. Date-of-sowing trials at Fargo have shown that when sowing is delayed until June, Marine has a decided advantage over the later varieties.

As shown in table 2, Marine yielded slightly more than Sheyenne or Bison at six of the seven stations in Minnesota for the 3-year period 1950–52. It yielded less than B5128 or Redwood when sown early. Limited data in Minnesota have shown that Marine is preferable to either B5128 or Redwood for late sowing.

Because of its resistance to diseases and its early maturity, Marine is well suited to that part of the North Central area where diseases or drought are likely to be a factor. It is also well suited to the drier areas of the Dakotas and wherever sowing is delayed in Minnesota or the Dakotas.

[1] Registered under cooperative agreement between the Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Dept. of Agriculture and the American Society of Agronomy. Received for publication May 1, 1953.

[2] Senior Agronomist, in charge, Seed-flax Investigations, Division of Cereal Crops and Diseases, B.P.I.S.A.E., A.R.A., U.S.D.A. Member of the Committee on Varietal Standardization and Registration charged with the registration of flax varieties.

[3] C.I. refers to accession number of the Division of Cereal Crops and Diseases.

Table 1.—Relative seed yield of Marine, Sheyenne, Redwood, Rocket, and B5128 flax in terms of percentage of Bison, the check variety, at six locations in the North Central area, when grown in Uniform Regional nurseries.

Variety	C.I. No.	Winnipeg		Park River, N. D.		Fargo, N. D.		Crookston, Minn.		Morris, Minn.		Brookings, S. D.	
		Years Grown	% of Bison	Years Grown	% of Bison	Years Grown	% of Bison	Years Grown	% of Bison	Years Grown	% of Bison	Years Grown	% of Bison
Marine (new)	1135	5	96	6	99	5	113	6	97	6	114	6	115
Sheyenne	1073	5	102	5	106	5	104	5	72	5	111	5	128
Redwood	1130	5	107	6	107	6	117	6	120	6	118	6	123
Rocket	1133	5	101	6	109	6	107	6	80	6	112	6	109
B5128	980	3	138	4	102	5	114	5	130	5	128	5	113
Bison	389	8	100	11	100	12	100	12	100	12	100	12	100

Table 2.—Average yield of Marine and standard varieties of flax grown in field plots at 7 locations in Minnesota in 1950–52.

Variety	C.I. No.	Rosemount	Waseca	Morris	Crookston*	Grand Rapids	Williams	S. W. Minn.
Marine	1135	18.6	17.3	27.1	14.6	13.8	21.1	20.9
Sheyenne	1073	17.3	16.3	26.0	15.0	13.1	19.6	19.3
Redwood	1130	21.7	19.3	28.8	17.7	13.1	23.3	21.6
B5128	980	18.5	17.2	26.0	17.4	11.9	21.9	23.0
Bison	389	16.0	12.5	25.2	14.8	11.5	16.7	18.0

* 1950–51 only.

Registration of Varieties and Strains of Crimson Clover I[1]

E. A. Hollowell[2]

IN ACCORDANCE with action taken by the Crop Science Division, A. S. A. (1),[3] crimson clover *(Trifolium incarnatum)* varieties became eligible for registration in 1951. Dixie is the first variety that has been approved for registration. It is apparent that varieties of crimson clover are similar to other small seeded legume varieties in that the improved characteristic may not be morphological in nature, making it impossible to readily distinguish the improved variety from the common by either seed or plant inspection. For that reason it is imperative that seed be produced under state certification in order that the improved characteristic of the variety be maintained and consuming farmers may be assured of the trueness to variety name. Procedures, regulations and standards for production of foundation, registered and certified seed have been developed by the International Crop Improvement Association (2).

DIXIE, REG. NO. 1

Dixie crimson clover originated in 1945 as a composite in equal proportions of three adapted similar farm strains,

Table 1.—Percentage of hard seed of crimson clover strains produced from volunteer stands at Statesville, N. C. June, 1942*

Strain	Percent Hard Seed		
	Sept. 17, 1942	Jan. 19, 1943	Aug. 8, 1943
Allen	71.25	65.75	61.94
Hardy	61.75	53.00	31.55
Thornton	64.00	51.75	40.55
Common	26.75†		

* Avg. of quadruplicate laboratory germination tests made at Beltsville, Md. using hand stripped and hand hulled seed.
† Seed from another planting, produced under similar environmental conditions.

[1] Registered under a cooperative agreement between the Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Dept. of Agriculture, and the American Society of Agronomy. Received for publication May 1, 1953.

[2] Principal Agronomist, Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Dept. of Agriculture. Member of the 1950–51 Committee on Varietal Standardization and Registration charged with the registration of crimson clover varieties.

[3] Figures in parenthesis refer to "Literature Cited."

Thornton, Allen and Hardy. Previous to compositing, these three strains had been tested over a period of seven years for volunteering (popularly called reseeding from shattered seed) and range of adaptation (3). Laboratory studies indicated that the strains had a relatively higher percentage of hard seeds than common crimson (table 1). The first evaluation trials were made in cooperative tests between the Georgia Coastal Plains, Georgia and North Carolina Agricultural Experiment Stations and the Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Dept. of Agriculture (tables 2, 3, 4 and 5). Other trials made by several state agricultural experiment stations of the southern region confirmed the results of the early trials. Later yield data indicated that Dixie produces high yields in addition to its ability to produce good volunteer stands, (4) (figure 1). Most of the southern states recommend this variety. Approximately 1,170,000 pounds of certified Dixie crimson clover seed were produced in 1950. Foundation seed of Dixie crimson is produced and distributed by the Georgia Agricultural Experiment Station.

Table 2.—Crimson Clover Observational Nursery, Experiment, Ga.

Source	F.C. No.	Fall stand 1938	Volunteer Fall 1939	Volunteer Fall 1940
Single row plots—Planted 1938				
White Flowered—Va.	13,099	Good	None	None
Germany	13,158	Good	None	None
Perkins—Tenn.	22,425	Good	None	None
Clear—Tenn.	22,428	Good	None	None
McUmber—Tenn.	22,433	Good	None	None
Hazelwood—Tenn.	22,434	Good	None	None
Thompson—Tenn.	22,603	Good	None	None
Dement—Tenn.	22,605	Good	None	None
Thornton—Ga.	22,609	Good	Excellent	Excellent
Gill—Ky.	22,612	Good	None	None
Dement—Tenn.	22,610	Good	None	None

Table 3.—Crimson clover strain test, Tifton, Ga. Seeded fall, 1940, on Bermuda grass.

Source	F.C. No.	Fall stands* 1940	Volunteer† stands—% 1941
Hardy—Ga.	31,023	Fair to Good	100
Allen—Ga.	31,041	Fair to Good	90
Thornton—Ga.	22,677	Fair to Good	100
Dement—Tenn.	22,672	Fair to Good	50
White Flowered—Va.	30,866	Fair to Good	2
Boyd—Ky.	30,610	Fair to Good	5
Miller—Tenn.	22,735	Fair to Good	3
Gill—Ky.	22,612	Fair to Good	5
McUmber—Tenn.	22,433	Fair to Good	20
Clear—Tenn.	22,428	Fair to Good	20
Thornton	22,736	Fair to Good	100

* Stands were somewhat spotted but sufficient for establishment of strain.

† All seed was permitted to fall on plots in June 1941. No seedlings were destroyed during summer and fall 1941.

Table 5.—Crimson clover variety forage and volunteering test, Beltsville, Md.—1944–45. Series I, forage plots triplicated 5 ft. x 23 ft. Series II, volunteering plots duplicated 7 ft. x 23 ft. Randomized block, seeded Sept. 28, 1944.

Strain	F.C. No.	Series I—Harvested full bloom stage May 26, 1945: Avg. yields green tons per acre (weed free(1))	Avg. estimated % weeds	Dry matter tons per acre
Allen	22,926	6.32	1.7	1.47
Hardy	22,929	4.94	3.7	1.17
Thornton	22,928	5.33	4.0	1.26
Auburn	31,795	3.65	15.0	0.86
Common	22,932	0.04	99.0	——

Series II *

Strain	Emergence† stand Oct. 7, 1944	% stand May 15, 1945	Volunteer stand Oct. 1, 1945
Allen	E-E	90–75	E-E
Hardy	E-E	50–50	E-G
Thornton	E-E	90–75	E-E
Auburn	E-G	50–25	F-F
Common	F-F	5–5	None

* Seed was harvested from area on June 25, 1945. Soil was disked immediately and seeded to sudan grass. Sudan grass was harvested first week in September 1945 and the soil was disked after removal of sudan grass.

† Stand legends: E = 90–100%, G = 80–90%, F = 70–80%, P = below 70%.

Table 4.—Crimson clover strain test, Statesville, N. C. Seeded Sept. 3, 1941. Plots 10 ft. x 10 ft., 3 replications, randomized block.

Source	F.C. No.	Stands Fall 1941	Volunteer* stands Fall 1942	Ground cover—% Jan. 1, 1943	Volunteer† stands Fall 1943
Allen—Ga.	31,184	Excellent	Excellent	67	Excellent
Hardy—Ga.	31,023	Excellent	Excellent	72	Excellent
White Flowered—Va.	30,866	Excellent	None	None	None
Boyd—Ky.	30,610	Excellent	None	None	None
Thornton—Ga.	22,792	Excellent	Excellent	55	Excellent
Miller—Tenn.	22,735	Excellent	None	None	None
Dement—Tenn.	22,673	Excellent	None	None	None
Dement—Tenn.	22,428	Excellent	None	None	None

* All seedlings on all plots were destroyed on Aug. 1, 1942.

† All seedlings on all plots were destroyed on Aug. 4, 1943.

FIG. 1.—Volunteering (reseeding) characteristic of Dixie crimson clover (left) compared to common crimson clover (right). Experiment, Ga., pictures taken May 4, 1951. Planted 1949. Estimated seed yields in 1950, 248 and 310 pounds per acre, respectively, based on two square yard samples. All seed except samples left on plots for volunteering. Courtesy of J. M. Elrod, Georgia Experiment Station, Experiment, Ga.

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Registration of Barley Varieties[1]

I. J. Johnson[2]

THE last report on registration of barley varieties was published in 1950 in the Agronomy Journal (1)[3]. A total of 18 varieties previously have been registered. Six additional varieties were approved by the Committee on Varietal Standardization and Registration in 1952. A description of the origin and important characteristics of these new varieties is given below.

EDDA, REG. NO. 19

Edda *(C.I. 7129)* was introduced in 1942 from Sweden to the United States and Alaska by the U. S. Department of Agriculture. Data on the origin and performance of Edda barley in Alaska have been summarized by Litzenberger and Bensin (2).

This variety was derived from a cross of Asplund × Vega made in 1925 at the Svalof Branch Station at Torsta, Sweden, and released to growers in Sweden in 1942. After its introduction to the United States, it was grown in Alaska for the first time in trials planted in 1945.

Edda is a 6-rowed, hulled, rough awned barley, with semi-lax spikes. Grains are medium large with blue aleurone color. This variety is early maturing, lodging resistant, high in yield and good in malting quality when grown in areas to which the variety is adapted. Edda is susceptible to covered smut. Yield trials comparing the performance of Edda with Olli are summarized in table 1.

KENBAR, REG. NO. 20

Kenbar *(C.I. 7574)* was developed cooperatively between the Kentucky Agricultural Experiment Station and

[1] Registered under cooperative agreement between the Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, and the American Society of Agronomy. Received for publication May 1, 1953.

[2] Professor in Charge of Farm Crops, Agronomy Department, Iowa State College, Ames, Iowa, and member of the Agronomy Society Committee on Varietal Standarization and Registration.

[3] Figures in parentheses refer to "Literature Cited."

Table 1.—Acre yields of Edda and Olli barley at two locations in Alaska, 1946 to 1950.

Variety	Location	Years Tested and Yield in Bu. Per Acre					
		1946	1947	1948	1949	1950	Avg.
Edda	Matanuska	49.3	33.7	62.6	42.7	80.3	53.7
Olli	Matanuska	34.6	21.4	51.2	39.4	69.0	43.1
Edda	Fairbanks	43.7	19.2	41.9	57.4	35.1	39.5
Olli	Fairbanks	34.6	23.1	33.4	54.5	29.1	34.9

the U. S. Department of Agriculture. It originated as a selection made by Dr. L. M. Josephson in 1944 from the Composite Cross X *(C.I. 6625)* supplied to the Kentucky Agricultural Experiment in 1942 by Dr. G. A. Wiebe. Because 18 parent varieties were used in producing Composite Cross X, the exact percentage of Kenbar is unknown. Data on the origin and performance of Kenbar have been summarized by Reid (3).

Kenbar is a bearded, 6-rowed, hulled, winter-type barley with semi-rough awns. Spikes are semi-dense and relatively short and erect. This variety, in comparison with the standard varieties of Kentucky 1 and Jackson 1, is higher in yield of grain, has greater strength of straw, shorter in plant height, 5 to 8 days earlier in maturity and 2 to 3 pounds lower in test-weight. In comparison with Missouri Early Beardless, which is the same in maturity date, Kenbar has been consistently far superior in yield, more winter hardy, and 4 to 5 pounds higher in test weight.

Kenbar is resistant to five races of loose smut *(Ustilago nuda)* and susceptible to two. In field tests with local collections of smut Kenbar averaged 2.1% of heads smutted while infection in Missouri Early Beardless was 18.5% in Kentucky 1, 35.5% and in Jackson 1, 69.6%. Kenbar also is highly resistant to mildew and scald but moderately susceptible to leaf rust.

HARBINE, REG. NO. 21

Harbine *(C.I. 7524)* was developed cooperatively between the Oklahoma Agricultural Experiment Station and the U. S. Department of Agriculture as a selection from Composite Cross III *(C.I. 5530)*. The final selection was made in 1935 by C. B. Cross, from the Composite Cross received in 1930 from Dr. H. V. Harlan, U. S. Department of Agriculture. Pertinent information on the origin and performance of Harbine has been summarized by Johnston and Schlehuber (4).

Harbine is a bearded, 6-rowed, hulled, rough-awned, mid-early, winter-type barley with somewhat short and erect spikes. It is especially adapted for combine harvest because of its relatively short straw and outstanding resistance to lodging. The name Harbine was derived from the words *"Harlan"* and *"combine"*, to signify its origin and this special characteristic. In comparison with Tenkow and Ward, two varieties most widely grown in Oklahoma, Harbine is equal to both in yield, equal to Tenkow but not as winter hardy as Ward, but superior in tillering and in test weight. Kernel size is somewhat small. It has considerable resistance to leaf rust and to several other leaf diseases, and is resistant to several races of loose smut *(Ustilago nuda)*.

MO. B-400, REG. NO. 22

Mo. B-400 *(C.I. 7568)* was developed at the Missouri Agricultural Experiment Station from the cross of Kentucky 5 with Missouri Early Beardless selections. The original crosses were made in 1936 by B. M. King and from bulk populations of four crosses a single plant selection in F_6 was made in 1942 by J. M. Poehlman. A detailed summary of its performances has been published by Poehlman (5).

Mo. B-400 is a bearded, 6-rowed, hulled, rough-awned, early maturing, winter-type barley adapted to central and southern Missouri. Its superior qualities are high grain yield, strong straw, winter hardiness in its area of adaptation, rapid vigorous growth of special value for fall pasture, and disease resistance. In the 6-year period, 1945–1951, when compared in Missouri with Reno and Missouri Early Beardless it outyielded the former by 3.7 and the latter by 12.9 bushels per acre. In 61 uniform barley yield tests conducted cooperatively with the U. S. Department of Agriculture in the northern winter barley area during the period 1948–1950, Mo. B-400 outyielded these two varieties by 0.7 and 11.4 bushels per acre, respectively. The higher yield and earliness equal to Missouri Early Beardless are of special importance in its area of adaptations.

In tests using artificial inoculation Mo. B-400 has been found to have a great deal of resistance to local collections of loose smut, *(Ustilago nuda)* but is susceptible to black loose smut, *(U. nigra)*, and to covered smut *(U. hordei)*. It also has moderate resistance to mildew and to spot blotch.

DICKTOO, REG. NO. 23

Dicktoo *(C.I. 5529)* originated as Selection No. 2 from an unkown cross made prior to 1917 at Dickinson, N. Dak. It was entered in yield trials at Nebraska in the early 1940's and distributed by O. J. Webster of the Nebraska Agricultural Experiment Station in 1952.

Dicktoo is a bearded, 6-rowed, hulled, rough-awned, winter-type barley. Its superiority, like Kearney (see Reg. No. 24), is in greater winter hardiness than the standard varieties grown in Nebraska. In a 6-year period tested at Nebraska the average winter survival of Dicktoo in field plots was 85 percent in comparison to 15 percent for Reno. In three of these six years the standard varieties, Reno and Ward, failed to survive the winters. In years when winterkilling is not severe, yields of Dicktoo are not greater than the above two varieties.

Tests made in Kansas and by the Barley and Malt Laboratory at Madison, Wis., show that the malting quality of Dicktoo has not been entirely satisfactory.

KEARNEY, REG. NO. 24

Kearney *(C.I. 7580)* was developed at the Nebraska Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture as a selection from Composite Cross III *(C.I. 5530)*. The initial selection from this Composite Cross was made by K. S. Quisenberry in 1941 at Lincoln, Neb. and was introduced in 1951 by O. J. Webster.

Kearney is a bearded, 6-rowed, hulled, rough-awned, winter-type barley. Its superior characteristic is greater winter hardiness than the standard varieties Reno and Ward with which it has been compared. In a 6-year test

the field survival of Kearney was 70 percent in comparison with only 15 percent for Reno. In years when winter killing is not serious the yield of Kearney has not been superior to that of Reno or Ward.

Malting tests with Kearney have been made at Nebraska and found to be very satisfactory. The Barley and Malt Laboratory at Madison, Wis., has reported mediocre malting quality, primarily because of small kernel size and high nitrogen.

In tests in Texas in 1950, Kearney was found to have some resistance to greenbugs.

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Registration of Sorghum Varieties, VI[1]

R. E. Karper[2]

APPLICATIONS for the registration of six new varieties of sorghum have been approved during the past year and are included in this report. The number of sorghum to meet requirements since the beginning of registration by the Society has now passed the one hundred mark.

SART, REG. NO. 96

Sart, a new variety of sorgo for sirup production was released and distributed by the U. S. Dept. of Agriculture and the Mississippi Experiment Station in 1951. Sart is noteworthy for its tall, heavy stalks, growing 12 to 15 feet on good land in a good season. It has large white seeds. It is a late maturing variety adapted to climatic conditions in Mississippi and the South. This new variety is resistant to lodging and to *Colletotrichum graminicolum,* and produces high yields of mild flavored sirup.

Sart is a plant introduction made by Carl Q. Grassl of the Division of Sugar Plant Investigations in 1945 from the Kordofan Province of Sudan, Central Africa. It was tested at the Mississippi Experiment Stations and outyielded Hodo, another late maturing and large growing variety, in acre yields of sirup.

COMBINE KAFIR-60, REG. NO. 97

Combine Kafir-60 is a double dwarf combine kafir obtained by crossing a double dwarf kafir selection to Texas Blackhul kafir and backcrossing an F_2 selection from that cross to Texas Blackhul, followed by selection for double dwarf height, earliness and adaptation to combine harvesting. The variety is typical Blackhul Kafir, the first pure double dwarf combine kafir type developed and released. This variety blooms in 60 days, a little earlier than Martin, and about ten days earlier than Texas Blackhul kafir. The stalks are juicy and stand up well in the field, with the typical kafir stiffness and resistance to charcoal rot. The head is erect on a long peduncle, the exsertion is good, and the seed-branches dry out as the plant matures, making it possible to combine the variety before frost. White seeds with black specks are borne in the heavy awnless heads. The test weight of the grain averages 60 pounds per bushel.

Although it is an early variety, Combine Kafir-60 has produced higher yields of grain than Martin and Texas Blackhul and only slightly lower yields than Plainsman.

The variety was bred by R. E. Karper, J. R. Quinby and Frank Gaines from the original cross made in 1944 and was released and distributed by Texas Agricultural Experiment Station in 1950.

REDBINE-60, REG. NO. 98

Redbine-60 is a red-seeded double dwarf combine variety which originated from a cross of Martin and a dwarf red-seeded strain, S. A. 7008X-10, a sib of Caprock. The name Redbine is a contraction of "red-seeded combine"; the number indicates the number of days from planting to anthesis. Redbine-60 blooms in 60 days, a few days earlier than Martin. The peduncles are long and the heads dry out rapidly as the plants mature, making possible earlier and easier combine harvesting. The seeds are medium in size and hardness, and the grain tests 59 pounds per bushel. The heads are awned.

Although Redbine-60 is earlier than Martin, it has yielded slightly more than Martin and has averaged as well as Plainsman in dry land tests.

The variety was bred by R. E. Karper, J. R. Quinby and Frank Gaines from the cross made in 1942 and was released and distributed by the Texas Agricultural Experiment Station in early 1950.

REDBINE-66, REG. NO. 99

Redbine-66 is a red-seeded double dwarf combine variety which was developed by the Texas Agricultural Experi-

[1] Registered under cooperative agreement between the Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Dept. of Agr., and the American Society of Agronomy. Received for publication May 1, 1953.

[2] Agronomist in charge of sorghum investigations, Texas Agricultural Experiment Station, Lubbock, Tex. Member of the Committee on Varietal Standardization of the Society charged with the registration of sorghum varieties.

ment Station from a cross of Martin and a sib of Caprock; the same parentage as Redbine-60. Redbine-66 blooms in about 66 days, later than Martin and a little earlier than Plainsman. The awnless heads are borne on long peduncles and the rachis and seed-branches dry out as the grain matures, making possible earlier and easier combine harvesting. The seeds are medium in size and hardness, with a test weight of 60 pounds per bushel.

Redbine-66 has longer peduncle and better exsertion and is taller than Plainsman. The seed color is brighter and lighter reddish-yellow than Martin, and the threshability is better than that of Martin or Plainsman. Grain yields of Redbine-66 have averaged around 12 percent higher than Martin and equal to Plainsman and Caprock.

Foundation seed of Redbine-66 was distributed to about 40 Certified Seed Growers in early 1950. They increased it during the winter in the Lower Rio Grande Valley and this new variety comprised 16 percent of the 1950 production of Texas Registered grain sorghum seed.

The variety was bred and selected by R. E. Karper, J. R. Quinby and Frank Gaines from the original cross made in 1942 and was released and distributed by the Texas Station in 1950.

HI-HEGARI, REG. NO. 100

Hi-Hegari is a tall variety of Hegari developed by the Texas Agricultural Experiment Station for forage and silage uses. It was bred and selected from a cross made in 1945 between Hegari and S. A. No. 5257–4, Standard Early Hegari, a tall mutation found in a field of Early Hegari in 1940. Hi-Hegari was bred and selected at the Lubbock Station by R. E. Karper, J. R. Quinby and Frank Gaines and was released and distributed by the Station in 1950.

Hi-Hegari differs from Hegari only by one gene for increased height; it has the same adaptation and maturity as Hegari. Hegari has long been noted as a palatable, high-quality forage which is relished by livestock as bundle feed and as silage.

In yield trials, Hi-Hegari has produced as much grain as Hegari and the standard grain sorghum varieties, while forage yields have averaged 16 per cent higher than Hegari.

POPSORGHUM, REG. NO. 101

Popsorghum is a new type of sorghum bred and developed at the Lubbock Station from a cross made in 1937. The variety was selected from a cross of Shallu and S. A. No. 5463–40–1, a dwarf Shallu-like popsorghum selection. S. A. 5463 has as one parent a selection from the cross (Feterita $\times$ Texas Blackhul kafir$_2$) $\times$ Shallu and Peti mil, a sorghum variety from Haiti as the other parent.

Popsorghum is a dwarf Shallu-like variety which blooms in 80 days, about a week earlier than Shallu. The plant color is tan. The Shallu-like panicle is erect and has long drooping seed-branches which typically hang to one side at maturity. The glumes are sienna-straw in color and are involute. The small white seeds are similar to popcorn in texture. The popping expansion is about 15:1, although expansions of up to 32:1 have been obtained with special techniques. Popsorghum makes a smaller popped kernel than does popcorn but is more tender and has less hull. The smaller puffs lie closer together and weigh more per unit of volume than popcorn and are just as flavorful and nutritious.

The yield of Popsorghum has been about equal to that of other Shallu types. Cooperative trials with the Rockefeller Foundation in Mexico indicates this variety as well adapted to those latitudes and of value for human food.

In areas where sorghums are adapted, Popsorghum is of definite value as a substitute for popcorn. Its value in commercial fields awaits further exploration and development in connection with tamalina flour, caramel and candied confections, puffed breakfast cereals, flour and meal and packaging of fragile articles for air transport.

Popsorghum was bred and selected by R. E. Karper, J. R. Quinby and Frank Gaines, and released by the Texas Station in 1950.

Registration of Oat Varieties, XVII[1]

H. C. Murphy[2]

THERE have been 124 varieties of oats approved for registration previous to this report. The first report (14),[3] published in 1926, included 42 "standard varieties of recognized importance" and 22 improved varieties. Twelve varieties were included in the 15th report published in March 1952 (13). The varieties Mo. 0-200 and Mo. 0-205 were submitted and approved for registration in 1952.

MO. 0-200, REG. NO. 125

Mo. 0-200 (C.I. 4626,[4] Mo. 04056) originated at the Missouri Agricultural Experiment Station, Columbia, Mo., as a selection from the cross Columbia × Bond–Iogold made by B. M. King in 1936. The purpose of the cross was to combine the earliness and vigor of the well adapted and popular Columbia variety with the disease resistance of the Bond–Iogold strain. The Columbia (C.I. 2820, Reg. No. 78) parent originated at the Missouri Station (12). The Bond–Iogold selection used as the other parent was developed by the Iowa Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture (7). After the cross was made in 1936 progenies were grown in bulk through the F_6 generation. The strain distributed as Mo. 0-200 was increased from a single plant selection in the F_8 generation made by J. M. Poehlman in 1941.

Mo. 0-200 was described in the application for registration by J. M. Poehlman as follows:

"Mo. 0-200 is similar to Columbia in plant and growth characteristics, and may best be described as a Columbia type. It is early, tall, vigorous and productive, with wide spreading panicles and a light green leaf color similar to that of Columbia. It stools heavily under most conditions. The grain is shorter and slightly plumper than Columbia, light red in color, with the striping on the back of the kernel, characteristic of Columbia. Mo. 0-200 has the Bond type of crown-rust and the Richland type of stem-rust resistance. Its smut resistance was derived from its Bond parentage. It is resistant to Victoria blight."

The superior characteristics of Mo. 0-200 are its early maturity, high yield, heavy bushel weight, resistance to smut, and resistance to the races of crown and stem rust most prevalent at the time of its distribution in 1949. It is susceptible to races 45, 57 and 101 of crown rust and to races 8 and 10 of stem rust. Since these races became common Mo. 0-200 has shown a greater tendency for lodging and is no longer superior in this respect to the parent variety Columbia.

Mo. 0-200 was tested in replicated plots in Missouri from 1943 to 1951. The average yield, bushel weight, date headed, height, lodging, and reaction to crown rust of Mo. 0-200 in comparison with Mo. 0-205, Columbia and Clinton during the 5-year period 1947–51 are presented in table 1. Additional agronomic and pathologic data have been published (1, 2, 3, 4, 5, 8).

MO. 0-205, REG. NO. 126

Mo. 0-205 (C.I. Nos. 4988 and 5323, and Mo. Nos. 04205 and 04197, respectively) originated at the Missouri Agricultural Experiment Station, Columbia, Mo., as a selection from the cross Columbia × Victoria–Richland made by B. M. King in 1936. The purpose of the cross was to combine the earliness and vigor of Columbia with the disease resistance of the Victoria–Richland selection. The Victoria–Richland selection (C.I. 3311) used as the other parent was developed by the Iowa Agricultural Experiment Station in cooperation with the U. S. Department of Agriculture (15, 16).

Progenies of the Columbia × Victoria–Richland cross were grown in bulk through the F_5 generation. The strain from which C.I. Nos. 4988 and 5323 were developed was increased from a F_5 generation head selection by J. M. Poehlman in 1940. This selection (C.I. 4803, Mo. 04014) was heterozygous for reaction to *Helminthosporium victoriae* Meehan and Murphy, and the two lines representing Mo. 0-205 were selected from C.I. 4803 in the F_8 generation. J. M. Poehlman and C. H. Kingsolver (10) found that C.I. Nos. 4988 and 5323 were homozygous for resistance to *H. victoriae* and intermediate for reaction to races 1, 45 and other races of crown rust common during 1947 to 1949. Although these selections do not possess the typical Victoria reaction to crown rust their moderate resistance afforded protection from heavy epiphytotics of crown rust in Missouri from 1947 and 1949. These results are in agreement with those of Rosen (11) and others who reported the recovery of an intermediate type of resistance to crown rust without susceptibility to *H. victoriae* from Victoria parentage.

Table 1.—Agronomic and pathologic data for Mo. 0-200 and Mo. 0-205 improved varieties of oats and Columbia and Clinton, standard varieties, in Missouri during the period 1947 to 1951.

Variety	Yield Bu.	Test Weight Lbs.	Date Headed	Height In.	Lodging %	Crown* Rust %
No. of comparison	28	28	14	23	22	7
Mo. 0–205	59.7	31.3	June 6	38	17	14
Mo. 0–200	54.3	31.5	June 2	37	37	24
Columbia	52.0	30.9	June 3	38	30	22
Clinton†	48.9	29.1	June 9	33	16	40

* Crown rust data recorded 1947 to 1950.
† C.I. 3971.

[1] Registered under a cooperative agreement between the B.P.I.S.A.E., A.R.A., U. S. Dept. of Agr. and the American Society of Agronomy. Received for publication May 1, 1953.

[2] Principal Pathologist, Division of Cereal Crops and Diseases, B.P.I.S.A.E., A.R.A., U.S.D.A. Member of 1953 Committee on Varietal Standardization and Registration charged with the registration of oat varieties.

[3] Figures in parentheses refer to "Literature Cited."

[4] C.I. refers to accession number of the Division of Cereal Crops and Diseases.

Mo. 0-205 was described in the application for registration by J. M. Poehlman as being similar to Mo. 0-200 and the Columbia parent in plant and growth characteristics. It is tall, vigorous, productive, with wide spreading panicles and a light green leaf color like Columbia. The straw, although more slender than that of Clinton, does not lodge easily because of its strong and vigorous root system. The gray colored kernels are striped like Columbia and usually somewhat darker. The hulls are thin and the test weight is high. In addition to their resistance to *Helminthosporium victoriae* and moderate resistance to prevalent races of crown rust the two sister strains, C.I. Nos. 4988 and 5323, making up Mo. 0-205 have been resistant to prevalent races of loose and covered smut and to races 2, 5 and 7 of stem rust.

Mo. 0-205 undoubtedly represents an outstanding contribution to oat improvement. Its superior characteristics have been high yield, high bushel weight, early maturity, and resistance to the prevalent races of crown rust, stem rust and both smuts. Mo. 0-205 has shown a wide range of adaptation. Its performance has been especially outstanding in Missouri, central and southern Illinois and Indiana, eastern Kansas and Nebraska, and southern Iowa. The dark grain color of Mo. 0-205 may detract from its popularity in some areas. It was moderately susceptible to Septoria black stem infection in the northern portion of the Corn Belt in 1952 where a tendency for weak straw was noted.

The sister strains C.I. Nos. 4988 and 5323 were distributed in 1951 to Missouri growers without bulking, under the designation Mo. 0-205. The two strains have been indistinguishable in the field. They apparently can be distinguished in the greenhouse by their contrasting reaction to powdery mildew, C.I. 4988 being resistant and C.I. 5323 being susceptible (6). Their yield and performance have been apparently identical under Missouri conditions. In uniform nurseries grown in a number of states C.I. 4988 has been somewhat higher in yield than C.I. 5323, indicating a wider range of adaptation for the former. Allotments of C.I. 4988 were distributed to the Illinois, Indiana, Wisconsin and Nebraska experiment stations for increase in 1951 and 1952. A purification of C.I. 4988 is being made in Missouri which probably will be designated as "foundation seed" of Mo. 0-205.

Mo. 0-205 was tested in replicated nursery plots in Missouri from 1947 to 1952 and in U. S. Department of Agriculture Cooperative Coordinated Uniform Oat Breeding Nurseries from 1948 to 1952. The average yield, test weight, date headed, height, lodging and reaction to crown rust of Mo. 0-205 in Missouri during 1947 to 1951, compared to Mo. 0-200, Columbia and Clinton is presented in table 1. Additional information on the performance of Mo. 0-205 has been issued (2, 3, 4, 5, 9).

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Registration of Soybean Varieties, III[1]

M. G. Weiss[2]

FIG. 1.—Soybean varieties Earlyana, Blackhawk, Lincoln, Hawkeye, and Adams (left to right) when grown at Ames, Iowa.

SOYBEAN varieties previously registered were described in the issues of the Agronomy Journal as follows: Boone, September, 1943; and Patoka, Gibson and Earlyana, May, 1944.

LINCOLN (REG. NO. 5)

Lincoln originated as an F_3 plant selection made in 1937 at the Illinois Agricultural Experiment Station from a natural cross, the parents of which are thought to be Mandarin and Manchu. It is similar in appearance to the Manchu varieties and selections in having tawny pubescence, indeterminate growth habit, prominent branches, predominately three beans per pod, dark brown pods at maturity, and round, yellow beans of moderate size with a prominent black hilum. Flower color, however, is white rather than purple, the characteristic color of the Manchu varieties. Lincoln has high oil content of beans, high iodine number of oil, excellent bean quality, moderate lodging resistance and height, resistance to the frogeye disease organism, and high bean yield. Its maturity classification is Group III, being adapted generally to east central Nebraska, central and southern Iowa, northern Missouri, and central portions of Illinois, Indiana, and Ohio.

In regional tests conducted by the Agricultural Experiment Stations of the North Central Region in cooperation with the U. S. Regional Soybean Laboratory, the superiority of Lincoln in agronomic and compositional characters was established. Agronomic and compositional performance of Lincoln in comparison with two previously grown varieties, Illini and Dunfield, in regional tests appears in table 1. Lincoln has been described in several publications (1, 2, 3, 4, 5, 6), and characteristics at maturity are shown in figure 1.

Lincoln was increased and released cooperatively and simultaneously in the states of Illinois, Indiana, Iowa, Missouri, Nebraska, and Ohio. Distribution was made to certified seed growers in 1944. It rapidly replaced virtually all of the acreages of Illini, Dunfield, and Manchu varieties and selections of similar maturity and some of the acreages of Mukden, Richland, and Chief. Peak production was reached in 1948 and 1949 when approximately one-third of the acreage in the United States was planted to Lincoln. The subsequent release of improved varieties adapted to regions immediately north and south of the optimum region for Lincoln resulted in the lateral narrowing of the region

[1] Registered under a cooperative agreement between the B.P.I.S.A.E., A.R.A., U.S.D.A. and the American Society of Agronomy. Received for publication May 1, 1953.

[2] Director of Field Crops Research, B.P.I.S.A.E., A.R.A., U.S.D.A. Chairman of the 1953 Committee on Varietal Standardization and Registration charged with the registration of soybean varieties.

Table 1.—Mean agronomic and compositional performance of Lincoln, Illini and Dunfield soybean varieties in regional tests,* 1944–51.

Variety	Yield—Bu. per acre	Relative Maturity—Days	Lodging†—Score	Height—In.	Bean† Quality—Score	Bean Size—Gms	Protein—%	Oil—%	Iodine Value—No.
Lincoln	31.3	0	2.2	37	1.7	14.1	40.3	21.7	134.4
Illini	28.0	+1.2	2.9	40	1.7	13.6	40.8	20.5	132.7
Dunfield	27.1	−0.9	2.9	37	2.0	15.0	39.7	21.7	127.9

* From 14 to 23 locations each year.
† From 1 (erect, excellent) to 5 (prostrate, very poor).

Table 2.—Mean agronomic and compositional performance of Hawkeye and Richland soybean varieties in regional tests,* 1945–51.

Variety	Yield—Bu. per acre	Relative Maturity—Days	Lodging†—Score	Height—In.	Bean† Quality—Score	Bean Size—Gms	Protein—%	Oil—%	Iodine Value No.
Hawkeye	32.3	0	1.5	36.1	1.4	17.3	41.2	21.0	129.0
Richland	28.4	+0.1	1.6	32.9	1.7	16.4	40.6	20.5	128.5

* From 18 to 23 locations each year.
† From 1 (erect, excellent) to 5 (prostrate, very poor).

in which it now is grown extensively. During 1951 and 1952 Lincoln was grown on nearly three million acres, which represents approximately 22% of the nation's acreage.

HAWKEYE (REG. NO. 6)

Hawkeye was developed by compositing selected lines from an F_3 plant of a cross between the Mukden and Richland varieties in a cooperative program between the Iowa Agricultural Experiment Station and the U. S. Regional Soybean Laboratory. It combines pronounced lodging resistance and earliness of the Richland parent with greater height of Mukden. Both parents are exceeded appreciably by its oil content and bean yield. It is characterized by pronounced upright growth, sparse branching, determinate growth habit, moderate height, purple flowers, gray pubescence, moderate resistance to bacterial blight, two- and three-seeded light brown pods at maturity, good bean quality, and moderately large ellipsoidal straw-yellow beans with an imperfect black (slate colored with brown outer ring) hilum. Its maturity is similar to that of Richland (Group II) but, unlike that parent, it bears few pods below the normal cutting height. Hawkeye is adapted generally to the lateral belt extending from northeast Nebraska and extreme south-east South Dakota, eastward through the northern regions of Iowa, Illinois, Indiana, and Ohio. Bean size exceeds that of either parent and most varieties commonly grown in the North Central Region.

Regional tests, conducted by the Agricultural Experiment Stations of the North Central Region in cooperation with the U. S. Regional Soybean Laboratory, established the superiority of Hawkeye in agronomic and compositional characters. Yield comparisons with Richland, the principal variety replaced, appear in table 2. Performance of Hawkeye has been described in several publications (7, 8, 9), and characteristics at maturity are shown in figure 1.

Hawkeye was increased and released simultaneously and cooperatively in the states of Illinois, Indiana, Iowa, Michigan, Nebraska, Ohio and Wisconsin. Initial seed distribution was made to certified seed growers in 1948. It rapidly replaced virtually all of the acreage of Richland and Mukden, some of the northern Lincoln acreage, and some of the most southern Earlyana acreage. During 1951 and 1952 more than three and one-quarter million acres of Hawkeye were grown, which constitutes more than one-fourth of the nation's soybean acreage.

ADAMS (REG. NO. 7)

Adams originated with an F_6 plant selection from the progenies of a cross between the Illini and Dunfield varieties in a cooperative program between the Iowa Agricultural Experiment Station and the U. S. Regional Soybean Laboratory. It resembles the Dunfield parent in having determinate growth, moderate branching habit, medium height, predominately three beans per pod, light-straw-colored pods at maturity, pale yellow to whitish yellow, moderately sized, slightly ellipsoidal beans, and high oil content. Like both parents, Adams has gray pubescence, white flowers, and buff to light brown hilum color of beans. In yield, lodging resistance, and earliness, Adams excels both parents. Its maturity classification is late Group II, being earlier than Dunfield, Lincoln, and Illini by approximately one, two and three days, respectively, and later than Hawkeye by four days. Its optimum area of adaptation is a lateral belt extending from east central Nebraska eastward through central Iowa and north central Illinois. This area coincides with the northern portion of the area to which Lincoln is adapted.

Regional tests, conducted by the Agricultural Experiment Stations of the North Central Region in cooperation with the U. S. Regional Soybean Laboratory, established slight superiority of Adams over Lincoln in lodging resistance and oil content and, although it is two days earlier in maturity, at least equal yield throughout the northern part of the area to which Lincoln is adapted (table 3). Performance and adaptation of Adams has been published (10, 11), and characteristics at maturity are shown in figure 1.

Table 3.—Mean agronomic and compositional performance of Adams, Lincoln and Hawkeye soybean varieties in regional tests,* 1947–51.

Variety	Yield—Bu. per acre	Relative Maturity—Days	Lodging†—Score	Height—In.	Bean† Quality—Score	Bean Size—Gms	Protein—%	Oil—%	Iodine Value No.
Adams	32.4	0	2.0	38.4	1.3	14.3	40.4	21.2	131.5
Lincoln	32.3	+2.2	2.1	37.8	1.5	14.0	40.5	21.1	134.8
Hawkeye	31.8	−3.9	1.5	36.2	1.4	17.3	40.9	21.1	128.9

* From 16 to 21 locations each year.
† From 1 (erect, excellent) to 5 (prostrate, very poor).

Table 4.—Mean agronomic and compositional performance of Monroe, Earlyana and Mandarin (Ottawa) soybean varieties in regional tests,* 1943–51.

Variety	Yield—Bu. per acre	Relative Maturity—Days	Lodging†—Score	Height—In.	Bean† Quality—Score	Bean Size—Gms	Protein—%	Oil—%	Iodine Value—No.
Monroe	27.0	0	2.1	37.0	1.6	14.8	42.7	19.6	131.6
Earlyana	27.5	+4.6	2.8	36.7	2.0	15.4	42.8	19.7	133.6
Mandarin (Ottawa)	26.2	−5.5	1.4	26.8	1.8	18.1	43.1	19.4	129.8

* From 9 to 14 locations each year.
† From 1 (erect, excellent) to 5 (prostrate, very poor).

Adams was increased in Iowa and released to certified seed growers of that state in 1949. In subsequent years it was increased and released in Illinois and Nebraska. As release of Adams followed release of the superior varieties Lincoln and Hawkeye, its need was not as acute as that of the latter varieties when they were released. However, the acreage of Adams is increasing annually. In 1952 slightly less than one half million acres were grown. It has replaced some of the northern Lincoln and some of the southern Hawkeye acreage.

MONROE (REG. NO. 8)

Monroe was developed from an F_3 plant of a cross between the Mukden and Mandarin varieties in a cooperative program between the Ohio and Illinois Agricultural Experiment Stations and the U. S. Regional Soybean Laboratory. It is a moderately tall variety with determinate growth habit and prominent side branches. It has white flowers, gray pubescence, light brown pods at maturity, and mostly two and three beans per pod. The beans are straw-yellow with a similarly colored hilum, ellipsoidal in shape, and slightly smaller than most varieties of comparable maturity.

In regional tests conducted by the Agricultural Experiment Stations of the North Central Region in cooperation with the U. S. Regional Soybean Laboratory, Monroe was found to have superior bean quality to Mandarin (Ottawa) and Earlyana and superior lodging resistance to Earlyana, the variety it largely is replacing (table 4). Monroe matures approximately six days later than Mandarin (Ottawa) and four days earlier than Earlyana, and its maturity classification is Group I. It is approximately equal in oil content and slightly inferior in yield to Earlyana and slightly superior in both characters to Mandarin (Ottawa). Performance of Monroe has been described previously (12, 13).

Monroe was increased and released simultaneously and cooperatively in the states of Minnesota, Ohio and Wisconsin. Because of its earliness it has been found superior to Earlyana in Northern Ohio where an early variety of soybeans is needed to precede wheat in the rotation.

Its greater height has made it preferable to Mandarin (Ottawa) on thin and sandy soil areas in Wisconsin and Minnesota where the latter variety has insufficient height for combining. Initial seed distribution was made to certified seed growers in 1949. The acreage of Monroe in 1952 is estimated at slightly more than 200,000 acres.

BLACKHAWK (REG. NO. 9)

Blackhawk is the product of an F_6 plant of a cross between the Mukden and Richland soybean varieties in a cooperative program between the Iowa Agricultural Experiment Station and the U. S. Regional Soybean Laboratory. Like the later selection from the same cross, Hawkeye, it is noted for outstanding lodging resistance, and high yield and oil content. It is characterized by pronounced upright growth, sparse branching, determinate growth habit, moderate height, white flowers, gray pubescence, light brown pods at maturity predominately with three beans, and medium sized, slightly ellipsoidal, straw-yellow beans with a buff to light brown hilum. Blackhawk matures appreciably earlier than either parent, approximately a day earlier than Earlyana and a day later than Habaro, and is in the Group I maturity class. Its region of adaptation extends from east-central South Dakota eastward through southern portions of Minnesota, Wisconsin and Michigan and extreme northern portions of Iowa, Illinois and Indiana.

Regional tests, conducted by the Agricultural Experiment Stations of the North Central Region in cooperation with the U. S. Regional Soybean Laboratory, established the superiority of Blackhawk over the varieties it is largely replacing, Habaro and Earlyana. Results of the regional tests, appearing as table 5, show Blackhawk is superior in yield, lodging resistance, bean quality, and oil content. Height is adequate for most of the heavy soils in the region of adaptation and, unlike Habaro, it bears its pods suffi-

Table 5.—Mean agronomic and compositional performance of Blackhawk, Habaro, and Earlyana soybean varieties in regional tests,* 1945–51.

Variety	Yield—Bu. per acre	Relative Maturity—Days	Lodging†—Score	Height—In.	Bean† Quality—Score	Bean Size—Gms	Protein—%	Oil—%	Iodine Value—No.
Blackhawk	28.8	0	1.8	33.7	1.6	15.7	41.3	20.3	129.1
Habaro	26.9	−0.8	2.1	28.3	1.8	18.3	43.5	18.9	132.3
Earlyana	27.2	+0.7	2.8	36.7	2.1	15.4	42.9	19.7	133.2

* From 10 to 14 locations each year.
† From 1 (erect, excellent) to 5 (prostrate, very poor).

Table 6.—Mean agronomic and compositional performance of Wabash, Chief, and Patoka soybean varieties in regional tests,* 1943–51.

Variety	Yield—Bu. per acre	Relative Maturity—Days	Lodging†—Score	Height—In.	Bean† Quality—Score	Bean Size—Gms	Protein—%	Oil—%	Iodine Value—No.
Wabash	30.3	0.0	2.1	40.7	1.6	14.3	40.3	21.2	129.4
Chief	29.6	−1.4	2.7	46.0	2.0	12.9	40.9	20.4	132.4
Patoka	28.5	+0.3	2.3	34.8	1.9	17.7	43.4	20.2	132.3

* From 13 to 17 locations each year.
† From 1 (erect, excellent) to 5 (prostrate, very poor).

Table 7.—Mean agronomic and compositional performance of Roanoke and Volstate soybean varieties in regional tests,* 1944–50.

Variety	Yield—Bu. per acre	Relative Maturity—Days	Lodging†—Score	Height—In.	Bean† Quality—Score	Bean Size—Gms	Protein—%	Oil—%	Iodine Value—No.
Roanoke	25.6	0	1.9	33.9	1.8	15.5	39.8	21.8	133.7
Volstate	24.9	−1.2	1.9	32.6	1.9	15.0	39.9	21.5	134.7

* From 23 to 39 locations each year.
† From 1 (erect, excellent) to 5 (prostrate, very poor).

ciently above the ground level to prevent excessive combine losses. Performance and adaptation of Blackhawk has been published previously (14, 15, 16), and characteristics at maturity are shown in figure 1.

Blackhawk was increased and released cooperatively and simultaneously in the states of Illinois, Indiana, Iowa, Michigan, Minnesota, South Dakota and Wisconsin. Initial seed distribution was made to certified seed growers in 1951. It is rapidly increasing in acreage and replacing Habaro and Earlyana in its region of adaptation. Approximately 300,000 acres of Blackhawk were grown in 1952.

WABASH (REG. NO. 10)

Wabash originated as an F_6 plant selection in a cross between the Dunfield and Mansoy soybean varieties in a cooperative program between the Purdue and Illinois Agricultural Experiment Stations and the U. S. Regional Soybean Laboratory. It is a moderately tall, upright variety with indeterminate growth habit and few or small side branches. It has white flowers, gray pubescence, light-straw-colored pods at maturity, predominately three beans per pod and bears its pods well off the ground. The beans are straw-yellow with a light brown hilum, slightly ellipsoidal in shape, and of medium size. Wabash is classified in maturity Group IV, maturing approximately a day later than Chief and the same time as Patoka. Its region of adaptation extends from northeastern Kansas eastward through central Missouri, southern portions of Illinois and Indiana, and northern Kentucky.

Regional tests, conducted by the Agricultural Experiment Stations of the North Central Region in cooperation with the U. S. Regional Soybean Laboratory, established the superiority of Wabash over Chief and Patoka in yield, lodging resistance, quality of beans, and oil content (table 6). It was also found superior in these characters to Gibson, another variety of comparable maturity that Wabash is replacing. Resistance of Wabash to frogeye leafspot hastened replacement of the highly susceptible varieties, Patoka and Gibson, in southern Indiana where the disease attained epidemic proportions during 1949 and 1950. Wabash has been described in several publications (17, 18, 19, 20).

Wabash was increased and released cooperatively and simultaneously in the states of Illinois, Indiana, Kansas and Missouri. Initial seed distribution was made to certified seed growers in 1949. Approximately one and one-third million acres of Wabash were grown in 1952.

ROANOKE (REG. NO. 11)

Roanoke was developed from a single plant selection from a mixed seed lot in a cooperative program between the North Carolina Agricultural Experiment Station and the U. S. Regional Soybean Laboratory. It is medium in height, resistant to excessive lodging, determinate in growth, and has pronounced side branches. It has white flowers, gray pubescence, light brown pods at maturity, predominately two beans per pod, and is resistant to shattering and to the frogeye leafspot organism. The beans are straw-yellow with a buff hilum, slightly ellipsoidal in shape, and moderately small in size. Roanoke matures approximately the same time as Volstate and Palmetto, and is classified as Group VII. It appears best adapted to the upper Coastal Plain and Piedmont areas of central North Carolina and northern portions of South Carolina, Georgia, Alabama, and Mississippi.

Regional tests, conducted by the Agricultural Experiment Stations of the Southern Region in cooperation with the U. S. Regional Soybean Laboratory, established the slight superiority of Roanoke over Volstate in yield and oil content (table 7), and appreciable superiority in these characters over Woods Yellow, Tanner, CNS, and Palmetto.

Roanoke was increased and released to growers in North Carolina in 1946 (21). In subsequent years it was increased and released in the states of Alabama, Georgia, Mississippi, South Carolina, and Virginia. Although adapted and grown over a wide area, the concentration of soybeans is not heavy in this area. Approximately 200,000 acres were grown in 1952.

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Registration of Varieties and Strains of Alfalfa, II[1]

L. F. Graber[2]

ALFALFA varieties previously registered are Ranger, Buffalo, and Meeker Baltic, and were described in the Agronomy Journal in August, 1943.[3]

NARRAGANSETT, REG. NO. 4

Narragansett alfalfa is a new variety developed at the Rhode Island Agricultural Experiment Station by T. E. Odland and associates. It is a very winter-hardy variety. Stands are readily established and it ranks high in yields where bacterial wilt does not decimate the stands. The greatest single weakness of the variety is its susceptibility to bacterial wilt disease. At the Wisconsin Agricultural Experiment Station, Narragansett was more susceptible to artificial inoculations of bacterial wilt in 1951 than Cossack alfalfa. In another field trial begun at the same station in 1949, Narragansett was more susceptible to bacterial wilt during an epidemic in 1950 than Williamsburg (a selection from Kansas common alfalfa) but less susceptible than Rhizoma alfalfa.

Where wilt was not prevalent, the yields of Narragansett have been at or near the top in several trials. At the Rhode Island Agricultural Experiment Station, Narragansett produced an average yield of 5.01 tons of hay per acre for a period of four years (1946–49) compared with 4.77 tons for Atlantic and 4.57 tons for Ranger. At eight locations in New York the yields of Narragansett for the first year after seeding averaged 3.32 tons per acre compared with 2.80 tons for Atlantic and 2.53 tons for Ranger. The second year yields of Narragansett, Atlantic and Ranger at seven locations in New York ranked similarly.

The foliage of Narragansett alfalfa has a dark green color. It has shown a substantial degree of tolerance to leaf diseases. In one trial at Tully, N. Y., the score on leaf spot diseases in 1948 was 4.2 for Narragansett, 6.8 for Ranger, 7.2 for Atlantic, 8.1 for Grimm, and 9.0 for Kansas Common. These ratings were on the basis of 1 for the least evidence of leaf spot and 10 for the most. Ratings on the prevalence of leaf spot based on the same scale, at Ithaca, N. Y., in 1949 were as follows: Narragansett, 6.3; Ranger, 8.0; Atlantic, 7.5; Grimm, 7.2; and Kansas Common, 8.6.

The crowns of Narragansett alfalfa are relatively wide and stems are for the most part erect. In trials at Wisconsin, the recovery of Narragansett alfalfa after cutting was somewhat like that of Cossack being less rapid than Ranger, Grimm, Atlantic or Buffalo alfalfa but more rapid than Rhizoma.

The flowers of Narragansett are highly variegated in color and when heavily in blossom this characteristic distinguishes Narragansett from varieties like Common, Grimm and others whose flowers show less diversity of color.

Narragansett alfalfa should fill a need in the areas of the north-eastern states and elsewhere in northern United States where wilt disease is not a serious factor. When seed is plentiful and relatively cheap it may be used for short rotations even on soils where infections of bacterial wilt in susceptible alfalfa are moderate in occurrence.

There is a very wide diversity of plant types in Narragansett. This characteristic may help to give Narragansett a wide range of culture in the northern half of the United States.

[1] Registered under a cooperative agreement between the B.P.I.S.A.E., A.R.A., U.S.D.A. and the American Society of Agronomy. Received for publication May 22, 1953.

[2] Professor of Agronomy, Wisc. Agr. Exp. Sta. Member of the 1953 Committee on Varietal Standardization and Registration charged with the registration of alfalfa varieties.

[3] Hollowell, E. A. Registration of Varieties and Strains of Alfalfa, I. Jour. Am. Soc. of Agron. 37:649–652. 1945.

Narragansett alfalfa is a synthetic variety of very diverse origin. The parental material came from several strains of yellow-blossomed alfalfa, *Medicago falcata,* and from variegated stocks, *M. media,* such as Grimm, Canadian variegated, Hardigan, Cossack, and Ladak.

Perhaps the most important single source of foundation material in the development of Narragansett alfalfa was seed of natural hybrids harvested by Dr. G. G. Moe from plants of the Don[4] variety *(M. falcata)* in 1920. At that time, this falcata type was growing in rows adjacent to Grimm and Canadian variegated alfalfa on the experimental grounds of the University of British Columbia, Vancouver, B. C. Don alfalfa was brought to the United States from Russia by the famed plant explorer, Professor N. E. Hansen, in 1906.[5]

Dr. Moe made several selections from the progeny of the Don hybrids *(M. falcata* × *M. media).* In the spring of 1927 he took seed from two F_1 hybrids (H-7 and H-156) and seed from 18 F_2 plants and also seed from 105 F_3 plants to Ithaca, N. Y. He sowed this seed in the breeding nursery at Cornell University in 1927. Here he studied the hybrid progenies and described them in an unpublished doctoral dissertation (Cornell University 1928). It was not until 1951 that R. A. Nilan[6] discovered the Don variety to be a diploid alfalfa.

Dr. Odland visited the Cornell breeding nursery in the summer of 1932. He was much impressed with the hybrids from British Columbia, and he obtained several clones of them, as well as clones of other strains from Dr. C. H. Myers of the New York Agricultural Experiment Station. From then on through 1937, Dr. Odland did extensive crossing, selfing, and selection for superior qualities with the many sources of material available. Natural selection, however, played a significant, if not a dramatic part in the breeding program. Following the New England hurricane of September 25, 1938, all top growth was killed to the ground by the heavy wind and salt spray. With such drastic treatment, only the most hardy lines made sufficient recovery to survive the winter of 1938–39. Crossing, selfing, and selection among the survivors continued until August, 1946, when seed of several strains was composited and sown in a one-fourth acre seed increase plot. The progeny from this planting was named Narragansett.

[4] Don alfalfa is a small, fine-stemmed, wide-spreading, deep yellow-flowered variety, seemingly worthless. However, its potency as a pistillate parent in natural crosses with Grimm and/or Ontario variegated was recognized in studies begun by Dr. Moe in 1920. Subsequently, he developed a breeding program, based mainly on mass selection in which six Don hybrids, H-7, H-56, H-71, H-156, and H-190 were used as parental material. After selections through six generations, the recent variety, Rhizoma, resulted. It has many characteristics in common with Narragansett.

[5] Professor Hansen's notes on this introduction were as follows: "Medicago falcata. From Moscow, Russia. * * * Sample of third generation under cultivation by Professor Williams of the Moscow Agricultural College, of seed obtained from wild plants in the Don Province of southeastern Russia."

[6] Nilan, R. A. Rhizoma alfalfa; chromosome studies of the parent stocks. Scientific Agriculture 31:123–126. March, 1951.

Notes

EFFECT OF TILLAGE INTENSITY ON ESTABLISHMENT OF BIRDSFOOT TREFOIL IN PASTURES[1]

BIRDSFOOT trefoil, *Lotus corniculatus* L., is a legume which has the potentiality for making a significant contribution to pasture production in many situations because of its ability to grow on moderately acid, drouthy, infertile, and imperfectly drained soil. However, several workers have reported sparse stands and slow establishment of birdsfoot trefoil under conditions of limited seedbed preparation (1, 2, 3, 4). This report presents the results of two experiments which were designed to determine the seedbed conditions requisite for the successful establishment of birdsfoot trefoil on the hill pastures of south-central New York.

[1] Part of a thesis submitted to the Graduate Faculty of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1951. The author wishes to express appreciation for the guidance of Dr. H. A. MacDonald, Professor in Agronomy, Cornell University, in these studies and to Dr. T. W. Barrett, Arizona State College, for his cooperation on the spring tillage experiment.

Summer Tillage Experiment

An experiment was laid out in an unproductive pasture on an acid soil classified as Lordstown stony silt loam with a 5% slope. The original vegetation consisted mainly of sweet vernal grass, *Anthoxanthum odoratum* L., and broadleaved weeds with some meadow fescue, *Festuca elatior* L. During the first week of August, 1948, five intensities of tillage were applied to plots 7 by 72 feet with four replications in a split plot design. The treatments in order of increasing intensity were (a) no tillage—check, (b) spring tooth harrowing twice to a depth of 1½ inches, (c) field cultivation twice to a depth of 4 inches, (d) field cultivation six times to a depth of 4 inches, and (e) plowing to a 6 inch depth followed by spring tooth harrowing twice. Two weeks after the initial tillage, 3,000 pounds per acre of limestone and 500 pounds per acre of 5–10–10 fertilizer were applied to the experimental area and all tilled plots were gone over twice with the spring tooth harrow. The plots were seeded on March 29, 1949, without further seedbed preparation or covering the seed. The subplots were sown with simple mixtures at the following rates per acre: (1) Empire birdsfoot trefoil 6 pounds and timothy, *Phleum pratense* L., 8 pounds, (2) Ladino white clover, *Trifolium repens* L. var., 2 pounds and orchard grass, *Dactylis glomerata* L., 8 pounds, and (3) wild white clover, *Trifolium repens* L., 2 pounds and Alta tall fescue, *Festuca elatior* var. *arundinaceae* (Shreb.) Wimm., 8 pounds.

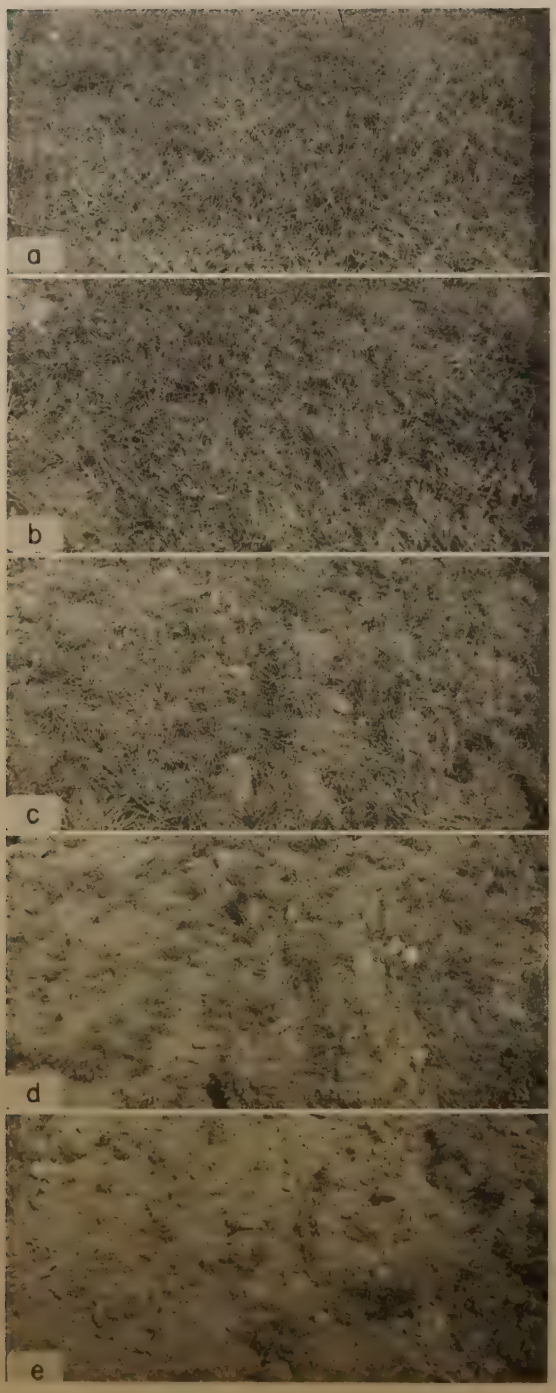

FIG. 1.—Tillage treatments used in summer tillage experiment: (a) check—no tillage, (b) spring tooth harrowed, (c) light field cultivated, (d) heavy field cultivated, and (e) plowed and harrowed.

Spring Tillage Experiment

This experiment was laid out in an abandoned pasture on an acid soil classified as Mardin channery silt loam having a slope of 10%. The original vegetation consisted of poverty grass, *Danthonia spicata* (L.) Beauv., broadleaved weeds, and a scattering of timothy. Three replications of a randomized block design were used with treatments consisting of six tillage intensities: (a) no tillage—check, (b) rototilling once with a garden rototiller to a depth of 1½ inches, (c) field cultivation four times to a depth of 4 inches, (d) disking four times with a weighted single section cutaway disk to a depth of 3 inches, (e) spring tooth harrowing four times to a 3 inch depth and (f) plowing to a 6 inch depth followed by spring tooth harrowing twice. These operations were performed on May 5, 1949. One month later, after applying 3,000 pounds per acre of limestone, the tillage treatments were repeated except for the plowed plots which were harrowed only. Then the tilled plots were rolled with a ring roller, seeded with a mixture of Empire birdsfoot trefoil 5 pounds per acre and timothy 6 pounds per acre, and rolled again to cover.

Results and Discussion

Summer Tillage Experiment

A stand count of the legumes was made on August 19, 1949. The three treatments of lower tillage intensity had very few birdsfoot trefoil seedlings. The heavy field cultivated plots had an average of 106 seedlings per square yard, and the plowed plots had an average of 173 seedlings per square yard (table 1) demonstrating a marked response to increasing intensity of tillage. There were no Ladino clover or wild white clover plants present regardless of treatment. Their failure to establish seemed to be due to drouth at a critical time during seedling development, since for a three month period beginning in late May only slightly over half of the normal rainfall occurred.

The forage yield harvested in 1950 on the plots seeded with the birdsfoot trefoil mixture responded to the tillage treatments in a manner similar to the birdsfoot trefoil stand. The yield increased from an average of 2,090 pounds per acre for the three lower tillage intensities to 2,870 and 3,780 pounds respectively for the heavy field cultivated and plowed treatments. The botanical composition estimates made at the time of harvest increased in stepwise agreement with the stand and yields from almost no legume at the three lower tillage intensities to 61 and 89% respectively for the heavy field cultivated and plowed treatments.

Spring Tillage Experiment

On July 20, 6 weeks after seeding, observations were made of the amount of original vegetation eliminated by the tillage treatments and counts were made of birdsfoot trefoil seedlings (table 2). The vegetation eliminated was estimated in terms of the percentage soil surface unoccupied by plants. The percent bare soil surface increased with tillage intensity from 2% for the check to a range of 22 to 30% for the rototilled, field cultivated, and disked treatments, to 44% for the spring tooth harrowed treatment, and 72% for the plowed treatment. The intensities of tillage obtained by the rototilled, field cultivated, and disked treatments were about comparable as shown by the similar values obtained for vegetation kill. The spring tooth harrow was more effective in this experiment than in the summer tillage experiment because a sharper implement was used and the moisture content of the soil was higher, making the sod more easily uprooted.

The population of birdsfoot trefoil plants increased from one plant for the check up to a maximum of 75 plants per square yard on the plowed plots. The correlation coefficient for the association between the stand of birdsfoot trefoil and the percent bare surface is 0.97, a highly significant

value. This demonstrates that there was a close relationship between the reduction in competition from original vegetation and the seedling stand.

The yield of forage harvested in 1950 and the proportion of birdsfoot trefoil in the forage showed the same trend as in the summer tillage experiment. Yield increased progressively with seedbed tillage intensity and vegetation kill from 800 pounds for the check plots to 3,000 pounds per acre on the plowed plots. The quality of the forage was enhanced by an increase from no legume for the check to 43% legume content for the plowed treatment.

The rototilled, field cultivated, and disked treatments were marginal with respect to the establishment of birdsfoot trefoil. They all reduced the amount of plant competition by approximately 25% and all resulted in a fair stand of birdsfoot trefoil seedlings initially. However, only one of the three treatments produced an appreciable amount of birdsfoot trefoil forage, and it was not associated with increased total yield as was the birdsfoot trefoil in the best two treatments.

The evidence from these two experiments shows that the effect of tillage in reducing the competition of the original vegetation is of primary importance to the establishment of birdsfoot trefoil during a season of limited rainfall.—W. A. WILLIAMS, *formerly Research Assistant in Agronomy, now Instructor in Agronomy, University of California.*

Table 1.—Effect of tillage intensity on stand, botanical composition, and yield on plots seeded to the birdsfoot trefoil mixture in the summer tillage experiment.

Tillage intensity	Bridsfoot Trefoil stand plants/ sq. yd.	Botanical composition Birdsfoot Trefoil %	Dry matter yield pounds/ acre
No tillage	9	3	1,890
Spring tooth harrowed	0	2	2,190
Field cultivated light	5	2	2,180
Field cultivated heavy	106	61	2,870
Plowed and harrowed	173	89	3,780
L.S.D. at 1% level	35	19	720

Table 2.—Effect of tillage intensity on vegetation kill, stand, botanical composition, and yield in the spring tillage experiment.

Tillage intensity	Bare surface %	Birdsfoot Trefoil stand plants sq. yd.	Botanical Composition		Dry matter yield pounds acre
			Birdsfoot Trefoil %	Desirable Grasses %	
No tillage	2	1	0	28	800
Rototilled	22	31	3	60	2,290
Field cultivated	24	27	0	59	2,000
Disked	30	29	17	38	1,740
Spring tooth harrowed	44	63	35	40	2,580
Plowed and harrowed	72	75	43	28	3,050
L.S.D. at 5% level	11	11	29	19	1,370

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CONTROLLED HYBRIDIZATION IN *LESPEDEZA STIPULACEA*[1]

INTRODUCTION and selection have revealed an array of biotypes in *Lespedeza stipulacea* Maxim., which differ in morphological characteristics, as well as reaction to diseases and insect pests. Several of the forms which have been so isolated are now available to the seed trade. The limitations of introduction and selection as the means of obtaining more productive varieties have been recognized. On the other hand, improvement through hybridization has been obstructed by the lack of feasible crossing techniques.

In gross morphological characteristics and in the mode of pollination, the chasmogamous and cleistogamous flowers are quite different, but the essential features of reproduction appear to be identical in the two flower types.[2, 3] In the showy (chasmogamous) flowers the style is longer than the anthers during all stages of bud development, thus permitting hand pollination in the bud stage without disturbing the anthers. The present study deals with methods of crossing. Emasculation was practiced in the first series of pollinations and omitted in two later series, in attempts to develop a suitable procedure for obtaining intraspecific hybrids.

Since normal seed set of the showy flowers had been observed to be higher in the field than under greenhouse conditions, all crossing attempts were confined to the field. Showy flowers were used in preference to the cleistogamous because of their larger size. The seeds obtained from the pollinations were germinated in Petri dishes during March of the following year and transferred to pots containing sterilized soil. When the seedlings were 1½ inches in height, they were transplanted to the field and later classified as hybrids or non-hybrids on the basis of flower color. The first generation progenies were readily classified since the pollinations had been confined to crosses in which the pale flower character occurred in the female parent.

In the first series of cross-pollinations during 1948, the buds were opened by slitting the upper portions of the standard and the anterior fused margin of the keel petals with a sharp probe. Gentle pressure was applied with the

[1] Joint contribution from the Division of Forage Crops and Diseases, B.P.I.S.A.E., U.S.D.A., and the Agronomy Department, North Carolina Agricultural Experiment Station, Raleigh, North Carolina. Published with the approval of the Director of Research as Paper No. 450 of the Journal Series.

[2] Hanson, C. H. Cleistogamy and the development of the embryo sac in *Lespedeza stipulacea*. Jour. Agr. Res. 67:265–272. 1943.

[3] ——— ———. *Lespedeza stipulacea*: Staminal morphology, meiosis, microgametogenesis, and fertilization. Agron. Jour. 45: 200–203. 1953.

FIG. 1.—Typical chasmogamous buds used in cross-pollination studies, and a mature flower; left to right, buds 2.7, 3.6, 4.1 mm. in length, mature flower.

thumb and forefinger on the ventral and dorsal sides of the bud to open it sufficiently for further manipulation. The anthers were carefully removed with the probe and with the aid of the binocular head loupe. Each bud was pollinated immediately after emasculation by brushing the stigma with the distal end of the sexual column from the pollen parent. Only two seeds were obtained from 42 cross-pollinations, representing a seed set of less than 5%. The plants grown from both seeds were hybrids.

When it became apparent that the above crossing procedure was not successful, emasculation was omitted in subsequent attempts. In other respects, the second series of cross-pollinations made during 1948 and a third during 1949 were made in the manner described for the first. Thirty-one mature seeds were obtained from 109 pollinations of non-emasculated buds during 1948. This is a seed set of 28.4%. Twenty-two of the 24 plants grown from these seeds were hybrids. During 1949, 30 seeds were obtained from 72 pollinations, which was a seed set of 41.6%. Twenty-two of the 23 plants maturing were hybrids.

During 1948 the pollinated buds were about 2–5 mm. in length. No record was made of the exact length of each bud. During 1949 each bud was classified into one of three categories of length: 2–3, 3–4, and 4–5 mm. (figure 1). In the latter year, there was a tendency for an increase in percent seed set with increasing bud size; 27, 38, and 56%, respectively, of the buds 2–3, 3–4, and 4–5 mm. in length set seed. Each of the 14 plants obtained from pollination in the first two categories were hybrids. Only one of the nine plants obtained from buds 4–5 mm. in length had developed from self-fertilization.

As to the relationship of bud size to time of anthesis, measurements of 70 buds undergoing anthesis on August 14, 1949, showed that their mean length on August 13 was 3.9 ± .05 mm. One day earlier it was 3.2 ± .03 mm. In a comparable study, 70 buds undergoing anthesis on August 20, were 3.8 ± .04 and 2.8 ± .03 mm. long on August 19 and 18, respectively.[4] When the 1949 cross-pollination data are taken into consideration, it is quite obvious that the ovary is receptive to fertilization at least one, and probably two days before anthesis. Inasmuch as mature flowers are usually 7–8 mm. in length, the data also indicate that rapid elongation occurs during the 24-hour period immediately preceding anthesis.

The extent of normal seed set of chasmogamous flowers during the period 1948–50 was also determined to obtain a better interpretation of the cross-pollination data. In each year, ten open flowers were tagged on each of 24 plants selected at random. The average seed set was 62, 61 and 68%, respectively, for the three years. This was somewhat higher than expected since taxonomists generally have considered the showy flowers in *Lespedeza* to be mainly sterile. The flowers, however, appeared very sensitive to manipulation, and the failures which resulted when emasculation preceded pollination were attributed to injury. Omitting emasculation in the crossing procedure had the additional advantage of being less time consuming.—CLARENCE H. HANSON, *Agronomist, Division of Forage Crops and Diseases, B.P.I.S.A.E. and Research Associate Professor, North Carolina Agricultural Experiment Station, Raleigh.*

[4] All measurements were made between 10 a.m. and 12 noon.

A RAPID METHOD FOR WASHING ROOTS[1]

FIELD studies on roots always have been laborious and time-consuming. A substantial part of the cost of investigations on root yields can be attributed to the thorough cleaning necessary to obtain reliable data. A rapid and relatively economical method for root washing, developed during the course of an investigation on the yields of aerial and subterranean parts of legumes (alfalfa, sweetclover, medium red clover and ladino clover) grown for green manures in Iowa, is presented here.

Root samples were obtained in the field from a 36 by 18-inch area. A 6 inches wide trench 12 inches deep was

[1] Contribution from the Iowa Agricultural Experiment Station, Ames, Iowa. Project 1205. Journal Paper J-2260.

FIG. 1.—Trays, held together by metal straps, are raised and lowered into the drum four times at half hour intervals, immersing the roots in the first step of the washing process.

first dug on the outside of this rectangle, following which the remaining block of soil was lifted up onto a canvas. The majority of the soil was then crumbled off the roots by hand, generally leaving soil particles of less than ¼-inch diameter adhering to the roots. The samples were then carried to a central location for further processing. There, the tops were cut from the roots at the crown, and the lower parts of the stems were easily washed free of soil under a faucet.

In 1951, the legume roots were washed by hand under a faucet. This method was very time-consuming, particularly since several hundred samples were processed. In 1952, they were placed separately in 14 by 9 by 2 inch trays with wooden sides and 8 by 8 hardware-cloth bottoms. These trays were then stacked, 14 at a time, in a 50-gallon drum previously filled with water containing one pound of a wetting agent (Calgon). The top tray was covered with hardware-cloth to prevent loss of roots. The 14 trays, securely held together by metal straps, were raised and lowered into the drum four times, at half-hour intervals (figure 1).

Following this immersion, which loosened and dispersed some of the soil, the 14 trays were placed on a slatted platform raised 24 inches from the bottom of a 8 by 3 by 3 foot watering tank. A one-hour sprinkling by means of overhead flaring rose sprinkling nozzles, one over each tray, fed by three-fourths inch pipes and garden hoses, completed the washing process (figure 2).

A comparison of the time required for hand-washing and for soaking and sprinkling samples is presented in

FIG. 2.—Fourteen trays on a slatted platform get an hour sprinkling from overhead nozzles, one over each tray, to complete the washing.

Table 1.—Time needed to wash 100 root samples by two different methods.

Kind of roots	Previous method (hand-washing)	Present method (soaking and sprinkling)
Alfalfa, sweetclover, medium red clover	50 man-hours	5.4 man-hours
Ladino clover	100 man-hours	5.4 man-hours

table 1. Hand-washing alfalfa, sweetclover or medium red clover roots under a faucet required an average of 30 man-minutes per sample, while a ladino root sample required one man-hour. The total time required for all manual operations of the overhead sprinkling method with previous soaking, regardless of the species, was 45 man-minutes for 14 samples. The total cost of the apparatus, excluding cost of watering tank and drum, was $60.00. It was constructed in about 70 man-hours.

On the basis of these results, this easy-to-construct and rapid method of root washing, which resulted in perfectly clean samples, should make possible a more intensive and accurate study of root yields of agronomic crops.—H. A. FRIBOURG, *Graduate Assistant, Agronomy Department, Iowa Agricultural Experiment Station, Ames, Iowa.*

TANNIN AND PALATABILITY IN SERICEA LESPEDEZA, *L. CUNEATA*

SERICEA lespedeza, *L. cuneata*, an important perennial legume adapted to a wide diversity of southern soils, is rejected as a forage crop by many farmers of the South because of its low palatability. Many workers have directly or indirectly attributed the low palatability of sericea to the relatively high content of tannin in the leaves of this species. However, positive evidence that the high tannin content of the leaves directly affects palatability has

been lacking. Plant breeders working with this species are particularly concerned about the relative importance of tannin in the species. If tannin content is important, then breeding programs must include analyses of tannin as an important part of the breeding method, if superior, palatable lines are to be secured.

Plants having inherently different contents of tannin have been found in commercial seed stocks of sericea in the breeding program at Beltsville, Md. Preliminary cooperative investigations between the Division of Forage Crops and Diseases, B.P.I.S.&A.E., and the Nutrition Section of the Animal Husbandry Division, B.A.I., U.S.D.A., were undertaken to determine the effect of tannin on palatability of sericea lespedeza. Cleistoganous (self-pollinated) seed from three plants of variable tannin content were germinated and seedlings planted in thumb-pots in the greenhouse in March 1952. Approximately 2,000 plants of each progeny were transplanted to the field in replicated plots with plants spaced in rows one foot each way in May 1952. The soil of the field, a clay loam, received an application of 300 pounds per acre of an 0–14–14 fertilizer before the plants were set.

The plants had reached a height of 14 to 18 inches by August 11. Since there was not enough material for grazing trials, the herbage was cut daily and fed green to the sheep. Approximately 12 pounds of green herbage from each of the three sericea progenies was cut each day and fed to two mature wethers during the six days, August 11–16, 1952. The sheep had been on good pasture up until this time and were given no other feed during the week of the trial. The green samples were cut each morning, chopped, sampled for analyses, weighed, and placed in three feed boxes in the feeding pen. Refused herbage from the previous day's feeding was collected, weighed, and sampled for analyses. The location for the green herbage of each sericea progeny in the feed box was determined daily at random.

The analyses of the composited samples as fed to sheep, percent leaves, and amounts consumed of the three sericea progenies were as follows:

	Sericea progenies		
	Number 1	Number 2	Number 3
Ash %	7.7	7.9	12.0
Crude fiber %	30.4	30.6	24.6
Crude protein %	14.9	15.3	16.4
Ether extract %	2.6	2.7	2.7
N.F.E. %	44.4	44.2	44.4
Leaves %	60.0	61.7	70.7
HCI Formaldehyde ppt. (Tannin)* %	4.8	7.6	12.0
Dry matter consumed (Kilos)	6.2	4.9	1.7
Relative consumption %	100	79	28

* Tannin values as determined from the HCI—formaldehyde precipitate are approximately 25% higher than total tannin as analyzed by the official methods.

The preliminary results of this study show a definite effect of tannin on palatability. As the tannin content of the herbage increased, the amount consumed by the two sheep declined very appreciably. These results are preliminary in that the quantity of herbage and the number of sheep fed were inadequate for more conclusive results. The fact that the high tannin progeny, Number 3, was lower in crude fiber, more leafy, and higher in crude protein, all desirable characteristics of a nutritious herbage, and was at the same time less palatable to sheep, indicates the importance of tannin in the species.—H. L. WILKINS, R. P. BATES, *and* PAUL R. HENSON, *Division of Forage Crops and Diseases, B.P.I.S.A.E., and* I. L. LINDAHL *and* R. E. DAVIS, *Nutrition Section, B.A.I., U.S.D.A., Beltsville, Md.*

Book Reviews

PLANT RESEARCH: 1. THE METHODS OF WATER CULTURE OF HIGHER PLANTS (246 pages) with an appendix on SYMPTOMS OF NUTRIENT DEFICIENCIES IN CROP PLANTS (48 pages)

(In German.) By Wilhelm Schropp. (South German Dairy Research Institute and Experiment Station.) Published as Volume VIII of the Handbook of Agricultural Research and Experimental Methods, Rudolf Herrmann, ed. Radebeul and Berlin, Germany: Neumann Verlag. (Illus.). 1951.

This volume is one of a series covering research methods in many branches of agriculture. The editor reports that seven previous volumes on research methods with soils, seeds, milk, and pesticides have appeared in two editions since 1941. Volumes not yet published are to deal with plant research through pot culture and field experimentation, and with research on feedstuffs, herbs and spices, and livestock.

The major subjects of Volume VIII include the kinds of water culture (i. e., circulating, aerated, with sand or cinder substrates, etc.), the care of the plants, the influence of environmental conditions, the techniques of determining yields or results, the chemistry and management of nutrient solutions and the use and significance of water culture in scientific investigations.

Drawings and photographs are effectively used to illustrate the details of equipment and procedure, some of which are uncommon and ingenious. In the chapter on various solutions, 22 different crop plants are given brief individual attention. A valuable feature of this book is the tables comparing the effect on the growth of several crops of about 20 different nutrient solutions devised by various investigators. The data in these tables were obtained by Dr. Schropp in extensive experiments on plant nutrition and the minor elements.

Dr. Schropp uses only a few pages to dispose convincingly of the economic potentialities of hydroponics and particularly of the allegedly higher yields per unit area from hydroponics as compared with those from fertile soils receiving comparably intensive management. The appendix describes nutrient deficiency symptoms of many crop plants, including deficiencies of minor elements. Both author and subject indexes are provided.

As might be expected, research conducted outside Germany during the recent war and post war years is not treated with the same thoroughness that characterizes the review of the literature for the preceding years. Nevertheless, this volume will be

most helpful to students and to experimenters undertaking water culture experiments. It is a comprehensive review of the various procedures and possibilities, effectively illustrated with numerous drawings and photographs.—R. J. MUCKENHIRN.

PLANT ANATOMY

By Katherine Esau. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd. 735 pages. (illus.). 1953. $9.00.

This book on plant anatomy treats in a general way the structure and development of seed plants with emphasis on the angiosperms. The subject is approached from the standpoint of developmental anatomy, but no attempt is made to put forth new theories or concepts or to revise existing ones. Where it is necessary to favor or support one theory or another, the author does it with the purpose of facilitating an understanding of the development, differentiation, function, and relationship of the various types of cells and tissues and the organs which they compose. If the author can be said to stress any one concept, it appears to be that "the plant is a unit on the basis of its development, evolution and structure." The anatomy of any particular species or family is discussed in detail only to the extent that it serves to illustrate a certain type of variation in structure and development.

The book is planned in an orderly fashion, beginning with a brief review of the plant body and then covering the cells, meristem and tissue differentiation, the tissues, the vegetative organs, and finally the flower, fruit and seed. It is generously illustrated with line drawings, and the halftones have been collected into a section of 85 plates at the end of the textual material.

Each chapter is opened with a review of the various concepts which have been put forward to interpret the subject to be discussed. From this aspect alone, the book is of definite value as a reference and guide for wider study as well as for a thorough treatment of plant anatomy. Another feature which will be of interest to many readers is the careful attention given to the origin of terminology. The straightforward style and explanations of basic terms and concepts should appeal to both students and professional botanists.—W. C. ROBOCKER.

CHEMICAL CONTROL OF INSECTS

By T. F. West, J. Eliot Hardy, and J. H. Ford. New York: John Wiley & Sons, Inc. XI 211 pages (illus.) 1952. $3.25.

The authors of this compact little book have presented a general survey of the important chemicals which are utilized for insect control. The subject matter is divided into 16 chapters. Major chapters cover fumigants, insecticides of plant origin, arsenicals, petroleum oils, coal tar derivatives, and the chlorinated persistent insecticides.

The chapters are written with information on the history, methods of using the insecticides and the chemistry of the compounds. Each chapter contains references, and an author and subject index is given at the end of the book. None of the literature subsequent to 1946 is included.

The science of insect control with organic chemicals has advanced very rapidly in the years since 1946 and recent literature on insecticides is voluminous. Some readers may wish to utilize a handbook of this kind in order to quickly obtain a general understanding of the status of chemical control of insects as World War II was ending.—J. T. MEDLER.

SUGAR, FACTS AND FIGURES, 1952

United States Cuban Sugar Council, D. M. Keiser, Chairman. 910 17th Street, N. W., Washington 6, D. C. 176 pages (illus.). 1952.

This book contains a wealth of figures and notes on the production and distribution of sugar and its relation to trade. Two chapters and a number of appendices are devoted to the various United States legislative Acts and international agreements concerning the sugar industry.

PRODUCTION OF FIELD CROPS

By T. K. Wolfe and M. S. Kipps. 4th ed. New York: McGraw–Hill Book Company, Inc. 495 pages (illus.) 1952. $6.50.

The fourth edition of Wolfe and Kipps' Production of Field Crops is a carefully revised and up-to-date successor of the widely-used classroom and reference text for the beginning course in field crops first published in 1924.

Of particular value in the current edition are new chapters on the history of American agriculture (the initial chapter), and on Grassland farming. Another significant change is a new, separate chapter on rice which is placed along with the other chapters on grain crops in Section II of the book. Further revision has substituted many more recent references for many which were cited in the earlier editions. In so doing, the authors have, in effect, rewritten some of the chapters to assemble a vast store of new information reported by investigators throughout the country. The authors, however, have continued to follow essentially the same outline adopted by the American Society of Agronomy in the early 1920's which was used in the preparation of the first edition.

Chapters in Section I continue to deal with the more generalized aspects of production common to most crops, covering in 19 chapters such subjects as the economic aspects of crop production, adaptation of crops, the value of good seed, fertilizers and lime, preparation of the seedbed, tillage, harvesting and storage, pasture and meadow management and crop rotation. Section II with separate chapters on the major crops or crop groups covers grains, legumes for seed, forage crops, root crops, fiber crops, tubers, sugar plants and stimulants.

PRINCIPLES OF FARM MANAGEMENT

By J. Norman Efferson. New York. McGraw–Hill Book Company, Inc. 431 pages. (illus.). 1953. $6.00.

This is a broad presentation of the general principles of farm management. It is intended by the author to be applicable to all areas and all systems of farming, and was written to cover all major problems involved in operating a farm business enterprise.

Of especial value as contributions to the growing literature on farm management are the first four chapters in which the author outlines the field of farm management, the need for and basis of farm management information, the place of economic theory in farm management and the collection and analysis of management data.

Leading off from that discussion, the book goes into comprehensive discussions on farm records, accounting systems, types of farming, price levels, production and labor efficiency, marketing practices, taxes and social security, managing farm finances, farm business arrangements, and other related topics.

The author has purposely avoided statistical tables illustrating management principles, explaining in part that "instruction is much more effective if illustrative material is based on a local situation, and it is suggested that each instructor use local and state materials for the demonstration of principles."

AMERICAN TOMATO YEARBOOK, 1953

Edited by John W. Carncross, 8 Elm St., Westfield, N. J. C. S. Macfarland, Jr. 40 pages. 1952. $2.00.

As with the 1952 edition, the American Tomato Yearbook for 1953 contains up-to-date information of interest to research workers, growers, shippers, canners and dealers. Contents include a list of recent references to tomato culture, diseases, pests and their control, and a key with illustrated map of all tomato diseases. There is also information under such headings as "Tomato Packing," "Hormones," and "Grade Requirements for Canning and Processing." Charts and graphs depict all aspects of the tomato industry.

MENTION

A Catalogue of Genetic Maize Types together with a Maize Bibliography. *Compiled by J. Weijer (with support by UNESCO). The Hague, Netherlands: Martinus Nijhoff, 9 Lange Voorhout. New York: Tice and Lynch, 21 Pearl St. Reprint from Bibliographica Genetica XIV, pp. 189–425. 22 guilders.*

Proceedings of the Crop Science Society of Japan. Vol. *21, Nos. 1 and 2. (In Japanese with English summaries.) The Crop Science Society of Japan, Faculty of Agriculture, Tokyo University. Nov. 1952.*

La Production des Tabacs de Coupe au Cambodge. *(in French) By L. Lollichon, Saigon, Indochina: Archives of Agronomic Research in Cambodia, Laos and Vietnam.*

Agronomic Affairs

MEETINGS

American Society of Agronomy and Soil Science Society of America, Nov. 16–20, Baker Hotel, Dallas, Tex.

National Collegiate Grain Judging Contest, Nov. 24, Kansas City, Mo.

International Collegiate Crops Judging Contest, Nov. 28, Chicago, Ill.

SOIL CONDITIONER SYMPOSIUM SCHEDULED FOR SOIL SCIENCE SOCIETY MEETING

A full four-hour session on the subject of soil conditioners and their effect on soil properties and plant growth is planned for the 1953 meeting of the Soil Science Society of America in Dallas, Tex., Nov. 16–20. It will be held as a joint meeting of the soil physics, soil chemistry and soil microbiology divisions of the Society.

At the 1952 meetings in Cincinnati, Ohio, preliminary reports were presented on soil-aggregating chemicals. The program was so well attended that SSSA officers decided on the 1953 symposium as a "follow up" meeting, according to Prof. EMIL TRUOG, SSSA vice-president and program chairman for the Dallas meetings.

JOINT COMMITTEE ON GRASSLAND FARMING WILL MEET NOV. 15 AND 16 IN DALLAS, TEX.

Meeting in conjunction with the American Society of Agronomy and the Soil Science Society of America, the Joint Committee on Grassland Farming has scheduled a two day session, Sunday and Monday, Nov. 15 and 16 in Dallas, Dr. FIRMAN E. BEAR, committee chairman, has announced.

Sunday will be devoted to a trip to the Charles Pettit Flat Top Ranch, Walnut Springs, Tex., under the direction of HOWARD B. SPRAGUE. Reservations must be made in advance.

C. N. SHEPPARDSON, Dean of the Texas A & M School of Agriculture, will be chairman of the Monday morning sessions. Discussions definitely scheduled at this writing are, Maintaining High Quality Ranges, B. W. ALLRED, SCS, Fort Worth, Tex., and Permanent Agriculture in the Southwest, H. B. SPRAGUE, Research Foundation, Renner, Tex.

In the afternoon session with R. D. LEWIS, director of the Experiment Station, College Station, Tex., as chairman, definitely scheduled discussions will be on Climate and Fertilizer in Relation to High-Protein Forage for the Southwest, HORACE J. HARPER, Samuel Roberts Nobel Foundation, Ardmore, Okla.; New Developments in Southwestern Livestock Agriculture, HENRY BIEDERMAN, editor, The Cattleman, Fort Worth; Future of Pasture Irrigation in the Southwest, M. L. PETERSON, University of California.

THOMAS C. LONGENECKER, head of the Soil Science Division, Texas Research Foundation, will preside at the evening session. G. T. HARLET, manager of the International Mineral and Chemical Corp., Carlsbad, N. Mex., will speak.

MEXICAN TOURS AVAILABLE FOLLOWING DALLAS MEETING

The National Railways of Mexico announces tours of Mexico at special rates available immediately after the Society meetings in Dallas. Information can be obtained by writing to F. Alatorre, General Agent, National Railways of Mexico, 2401 Transit Tower, San Antonio 5, Tex.

WESTERN GRASS BREEDERS HAVE SEVENTH PLANNING CONFERENCE

Thirty-four participants representing 11 western states attended the seventh work planning conference of the Western Grass Breeders June 22 to 24 at the Northern Great Plains Field Station, Mandan, N. Dak., with G. A. ROGLER and the station staff as hosts.

Called one of the most successful meetings of the group, it featured a symposium on wheatgrasses. DAVE H. HEINRICHS, Swift Current and R. P. KNOWLES, Saskatoon, Sask., were special guests who contributed to the symposium.

Officers elected for the coming year are: J. R. HARLAN, Oklahoma, president; R. E. STITT, Montana, vice president; and K. I. PATTERSON, Washington, secretary. Outgoing president is R. M. LOVE, California. Harlan and Stitt had served as vice president and secretary during the past year.

In addition to the symposium, each state reported on breeding methods and objectives in its grass improvement program, and on uniform nursery trials and performance of species and strains tested to date.

Other special guests were JENS CLAUSEN and WILLIAM HIESEY, Carnegie Institution of Washington, D.C., and E. H. STANFORD of California who reported on the blue grass program carried on in cooperation with the Pacific Nursery Division of the Soil Conservation Service.

The 1954 meeting will be held at Oklahoma A. and M. College, Stillwater, Okla.

THORNE IS NEW PRESIDENT OF WESTERN SOCIETY OF SOIL SCIENCE

D. W. THORNE, Utah State Agricultural College, Logan, Utah, was elected to succeed MAURICE N. LANGLEY, head, Land Use and Settlement Branch, Bureau of Reclamation, Yuma, Ariz., as president of the Western Society of Soil Science at the group's 1953 annual meeting, June 15–18, in Santa Barbara, Calif.

New vice-president, ROBERT M. HAGAN, assistant irrigation technologist, University of California, Davis, Calif., has served as secretary-treasurer during the past year, and he was replaced in that office by DANIEL G. ALDRICH, Jr., Citrus Experiment Station, Riverside, Calif.

The Society will meet in Pullman, Wash., in 1954, with the State College of Washington serving as host.

SOIL SCIENCE CONGRESS PAMPHLET IS AVAILABLE

Copies of the First Circular announcing the program of the Fifth International Congress of Soil Science to be held in August, 1954, in Leopoldville, Belgian Congo, are available at the offices of the American Society of Agronomy. Anyone desiring a copy may obtain one by addressing a request card to the Society at 2702 Monroe St., Madison 5, Wis.

FROLIK HEADS CORN BELT BRANCH

E. F. FROLIK, head of the Agronomy Department, University of Nebraska, was named chairman for the coming year of the Corn Belt Branch of the American Society of Agronomy. His selection was announced at the group's summer meeting in Wooster, Ohio, June 22–23.

He succeeds G. W. VOLK, Ohio State University agronomist, who served during the past year. M. O. PENCE, Purdue University, Lafayette, Ind., was re-elected secretary-treasurer of the group.

Registered attendance at the 1953 summer meeting of the Corn Belt Branch was 207. The Branch will hold its 1954 meeting in Lincoln, Nebr., with the University of Nebraska serving as host institution.

Visiting agronomists at Wooster were conducted over experimental crop and soil plots of the Ohio Agricultural Experiment Station. At their annual dinner, they heard a talk by A. W. MARION, director of the Ohio Department of Natural Resources.

A tentative schedule of future meetings of the Corn Belt Branch following the Nebraska meeting was announced as follows: 1955, Iowa State College, Ames, Iowa; 1956, Purdue University, Lafayette, Ind.; 1957, North Dakota State College, Fargo, N. Dak.; 1958, University of Minnesota, St. Paul, Minn.

USDA PRESENTS SERVICE AWARDS

Seven U. S. Department of Agriculture employees and two work units received distinguished service awards and 105 employees and 13 work units received superior service awards in ceremonies in Washington in May.

Among recipients of the distinguished service awards were the following:

FRED C. BISHOPP, Bureau of Entomology and Plant Quarantine, Washington, D. C., plant pest control; STERLING B. HENDRICKS, B.P.I.S.A.E., Beltsville, Md., contributions of fundamental knowledge to the advancement of science; HENRY A. JONES, B.P.I.S.A.E., Beltsville, Md., genetics of cytoplasmic male sterility; ERNEST R. SASSCER, Entomology and Plant Quarantine, Washington, D. C., plant pest control; R. W. TRULLINGER, Office of Experiment Stations, Washington, research administration.

Superior service awards were presented to the following:

EMORY D. ALEXANDER, Extension Service, Athens, Ga., agronomy extension work; CHARLES B. BISBEE, Soil Conservation Service, Watersville, Wash., soil and water conservation in wheat-growing areas; ROGER Q. BROWN, Extension Service, Charleston, Mo., crop production; HINSON C. COLE, Soil Conservation Service, Price, Utah, flood emergency work; CLYDE W. DORAN, Forest Service, Delta, Colo., range reseeding and noxious plant control; CARL H. GADDIS, Entomology and Plant Quarantine, Lafayette, Ind., sweet potato weevil control in storage; FRANCIS L. GREEN, WILLIAM G. PATTERSON and WALTON C. SIZEMORE, all of Soil Conservation Service, Bishopville, S. C., livestock watering and irrigation; CARL P. HARTLEY, B.P.I.S.A.E., Beltsville, Md., forest management and forest products conservation; CLINTON M. JONES, Soil Conservation Service, Emporia, Va., training technicians, drainage; MERTON C. LANE, Entomology and Plant Quarantine, Walla Walla, Wash., wireworm control on irrigated lands; MARSHALL W. STONE, Entomology and Plant Quarantine, Whittier, Calif., wireworm control on irrigated lands; JOHN M. MILLER and DAVID A. ISLER, both of Entomology and Plant Quarantine, Beltsville, Md., development of dual sprayer; HOWARD B. RICHARDSON, and ROBERT W. WEBB, both of Production and Marketing Administration, Washington, D. C., relation of raw cotton quality to results in textile processing; EDD ROBERTS, Extension Service, Stillwater, Okla., development of Land Judging contests; EUGENE S. SCHULTZ and FREDERICK J. STEVENSON, both of B.P.I.S.A.E., Beltsville, Md., potato diseases; GEORGE STEWART, Foreign Agricultural Service, crop improvement in Iran; ERHARDT P. SYLWESTER, developing seed testing service and control of noxious weeds.

Among the work units receiving superior service citations were Soil Conservation Service units at the following locations:

Culpeper, Va., Albuquerque, N. Mex., Idabel, Okla., Little Rock, Ark., and Wills Point, Tex.

OCT. 15 IS FULBRIGHT APPLICATION DEADLINE

Applications for Fulbright Scholarship Awards for 1954–55 will be received until Oct. 15. Competition is again specifically for university lecturing and postdoctoral-level research. Application forms and additional information are obtainable from the Conference Board of Associated Research Councils, Committee on International Exchange of Persons, 2101 Constitution Ave., Washington 25, D.C.

PROF. E. J. GRAUL RETIRES AT WISCONSIN

EDWARD J. GRAUL, professor of soils, retired at the end of the past academic year from the University of Wisconsin where he had served continuously since his graduation in 1911. During his career he had given more than 7,500 students their basic training in soils, and was known throughout the state as a popular speaker at extension meetings on soil improvement.

GEOPHYSICAL UNION CITES IOWA SOILS SCIENTIST

Dr. DON KIRKHAM of Iowa State College has received a citation from the American Geophysical Union honoring his paper, Seepage into Drain Tubes in Stratified Soil, as the best hydrology paper published in the Transactions of the American Geophysical Union in 1951. The selection was announced in May at the annual meeting of the Union in Washington.

DEADLINE

Organizational, personnel and commercial news items are always welcome in the Agronomic Affairs columns of the *Agronomy Journal*. Items for any issue should be in the hands of the editor by the 22nd of the preceding month. Items for the September issue should be mailed to reach this office by Aug. 22.

NEW ARKANSAS FERTILIZER TAX WILL SUPPORT STATE'S SOIL TESTING PROGRAM

Revenue from a new state tax of 25 cents per ton on all fertilizer sales will be used to support the soil testing and research programs of the Arkansas Agricultural Experiment Station. Effective June 11, the levy was enacted by the 1953 Arkansas state legislature.

It brings the state tax on fertilizer to 37½ cents per ton. An earlier 12½ cent tax will continue to revert to the state for other purposes. Dean LIPPERT S. ELLIS of the College of Agriculture and director of the Arkansas Extension Service announced that a new soil testing laboratory will be built near Marianna, Ark., and the Fayetteville laboratory will be enlarged as a result of the expanded program.

THATCHER RETIRES AT OHIO

L. E. THATCHER of the Department of Agronomy at the Ohio Agricultural Experiment Station, Wooster, was presented with a watch by his associates at the station and in the Agronomy Department of Ohio State University, Columbus, on June 23. Mr. Thatcher, who has been stationed at Wooster since 1918 and who was with the Ohio State University from 1914 to 1918, is retiring from active duty. He is widely known for his work in developing Thorne wheat, now estimated to occupy one-third of the present U. S. acreage of soft red winter wheat. Mrs. Thatcher was also presented with a gift certificate by Mr. Thatcher's associates. The presentation was made at the annual dinner of the Corn Belt Branch of the American Society of Agronomy, at Wooster.

NEWS ITEMS

Faculty members of the soils department, University of Wisconsin College of Agriculture, have named O. J. ATTOE as department chairman to succeed EMIL TRUOG who will retire from the faculty next June 30. The new appointment became effective July 1.

—A—

Colorado A & M college, Fort Collins, Colo., recently obtained title to a 160-acre farm from the San Luis Valley Potato Improvement association with whom the college had jointly operated the farm since 1940. The farm will be used for crop research and as a demonstration farm.

A

MYRON W. BURGER, assistant weed supervisor in western South Dakota, has resigned that position to accept other employment.

A

Dr. THEODORE E. ODLAND, head of the University of Rhode Island agronomy department and recipient of a Fulbright Fellowship, is now engaged in research and lecturing on forage crop culture and breeding at the Agricultural College of Norway in Vollebekk near Oslo. He is working with Dr. HAKON WEXELSEN noted for research in forage crops and plant breeding. Prof. DONALD A. SCHALLOCK will be acting head of the department until Dr. ODLAND returns after Dec. 31.

A

Dr. HARVEY P. NEWTON, former soil scientist with the Maya Corp., Montclair, N. J., is now in charge of the Pennsalt Health and Agriculture Service in Venezuela. The PHAS project is engaged in investigating fertility status of Venezuelan soils.

A

Since July 1, Dr. GORDON S. TAYLOR has been in charge of the Connecticut Experiment Station tobacco laboratory at Windsor. He had been stationed at New Haven since 1952 and was at Iowa State college prior to that time. HENRIK DE ROO has been named agronomist at Windsor filling the vacancy left by the resignation of T. R. SWANBACK.

—A—

Since June 15, BILLY BIRD BRYAN has been with the Arkansas Experiment Station as assistant agricultural engineer doing research in cotton mechanization and irrigation. For the past three years he had been employed as extension irrigation engineer at Kansas State College.

A

C. E. SCARSBROOK has accepted a position as associate soil chemist at Alabama Polytechnic Institute, Auburn, Ala. He is in charge of soil nitrogen research and will teach soil physics. He was formerly associate agronomist at Louisiana State university.

Dr. JAMES MCGINNIS, poultry nutritionist at Washington State College has been with the Chas. Pfizer Co., Terre Haute, Ind., for the past year assisting in the establishment of a research farm and laboratory. With Dr. HANS GUNTHARDT at Washington State College, he had been engaged in studying factors affecting the nutritional value of feed ingredients.

—A—

At its 1953 Commencement, Michigan State College conferred the honorary degree of Doctor of Agriculture upon ERNST HART, executive vice-president of Chemical Divisions, Food Machinery and Chemical Corp.

—A—

JONAS J. CHRISTENSEN was named to succeed E. C. STAKMAN as head of the department of plant pathology and botany at the University of Minnesota upon the latter's retirement. In another change at that university, LEON SNYDER has succeeded W. H. ALDERMAN as head of the horticulture department.

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Dr. B. A. KRANTZ returned in June to the Southwestern Irrigation Field Station, Brawley, Calif., from two months in Venezuela where he had assisted the IBEC (Rockefeller) Research Institute in organizing a research program for increasing corn production.

COMMERCIAL NEWS

Dead Sea Works, Ltd. resumed development of potassium, magnesium and bromine deposits in the Dead Sea this summer with the help of a 2½ million dollar loan from the U. S. Export-Import bank. The company has acquired the Israel assets of Palestine Potash, Ltd., which had developed the Dead Sea deposits for over 20 years prior to the Arab–Israel war. Another Israel firm, Fertilizers and Chemicals, Ltd. of Haifa, has announced plans for establishing a multi-million dollar integrated chemical industry for production of nitrogen fertilizers, phosphates, sulphuric and phosphoric acids, soda ash and magnesia compounds. A new plant at Haifa will concentrate on production of nitrogen fertilizers. Other plants are near Tel Aviv.

—A—

The combination of cheap diesel power with front-end loading up to 5,000 pounds capacity is featured in the Baker–Lull Shoveloader, mounted on a Sheppard industrial wheel-type tractor, recently introduced by Baker–Lull Corp., materials handling equipment manufacturers in Minneapolis, Minn.

—A—

Promotion of HENRY S. CURTIS to manager of production and engineering of the Diamond Alkali Organic Chemicals Division, Inc., was announced in June by the Diamond Alkali Co.

—A—

Nitrogen Division, Allied Chemical and Dye Corp. expects its new ammonia plant at La Platte, Neb., to be completed and in production in the Spring of 1954. The plant will produce about 75,000 tons of anhydrous ammonia per year, of which a large part will be converted into various grades of urea.

—A—

A new bulletin offered by Richardson Scale Co., Clifton, N. J., describes the firm's new constant-weight continuous feeder. Typical products handled include cattle and poultry feeds, grains, limestone and dry, free-flowing chemicals.

PERSONNEL SERVICE

THE PERSONNEL SERVICE column is provided without charge to American Society of Agronomy and Soil Science Society of America members. For all others, a charge of $2.00 is made. Insertions are limited to 100 words, and should be submitted in duplicate. An item will be inserted one time only, but will be given a code number which will be carried for five additional insertions, unless a discontinue order is received.

The following applications, published in earlier issues of the *Agronomy Journal*, are still available: 2–1, 4–2.

Position desired. Training in genetics, biometry, agronomy and botony. M.S. and Ph.D. (nearly completed) from Iowa State. Experience in Experiment Station plant breeding work. Married, age 26. Interested in opportunity for exercising initiative, particularly in research problems 7–1.

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H. C. Knoblauch ---------- Washington
C. H. Mahoney ---------- Washington
H. B. Mann ---------- Washington
J. W. McKericher ---------- Washington
M. H. McVickar ---------- Washington
G. R. Muhr ---------- Washington
M. Y. Nuttonson ---------- Washington
J. D. Romaine ---------- Washington
A. F. Sander ---------- Washington
W. J. Sando ---------- Washington
B. T. Shaw ---------- Washington
R. W. Simonson ---------- Washington
G. D. Smith ---------- Washington
E. V. Staker ---------- Washington
J. H. Stallings ---------- Washington
H. M. Steece ---------- Washington
J. G. Steele ---------- Washington
D. Stewart ---------- Washington
F. B. Stewart ---------- Washington
A. F. Swanson ---------- Washington
J. R. Taylor, Jr. ---------- Washington
M. W. Taylor ---------- Washington
G. L. Terman ---------- Washington
J. Vergara ---------- Washington
H. N. Watenpaugh ---------- Washington
W. A. Wheeler ---------- Washington

FLORIDA

R. J. Allen, Jr. ---------- Belle Glade
R. A. Bair ---------- Belle Glade
W. G. Blue ---------- Gainesville
B. A. Bourne ---------- Clewiston
O. C. Bryan ---------- Lakeland
M. Drosdoff ---------- Gainesville
R. W. Earhart ---------- Gainesville
C. F. Eno ---------- Gainesville
W. T. Forsee, Jr. ---------- Belle Glade
N. Gammon, Jr. ---------- Gainesville
E. O. Gangstad ---------- Belle Glade
C. M. Geraldson ---------- Bradenton
V. E. Green, Jr. ---------- Belle Glade
L. C. Hammond ---------- Gainesville
W. D. Hanson ---------- Gainesville
H. C. Harris ---------- Gainesville
E. M. Hodges ---------- Ona
F. L. Holland ---------- Winter Haven
E. S. Horner ---------- Gainesville
F. K. Hull ---------- Gainesville
A. E. Kretschmer, Jr. ---------- Belle Glade
J. L. Malcolm ---------- Homestead
D. E. McCloud ---------- Gainesville
D. D. Morey ---------- Gainesville
J. R. Neller ---------- Gainesville
J. B. Pate ---------- Belle Glade
W. K. Robertson ---------- Gainesville
W. H. Sachs ---------- Orlando
C. C. Seale ---------- Belle Glade
P. H. Senn ---------- Gainesville
F. B. Smith ---------- Gainesville
W. F. Spencer ---------- Lake Alfred
G. D. Thornton ---------- Gainesville
G. M. Volk ---------- Gainesville
A. T. Wallace ---------- Gainesville

GEORGIA

W. E. Adams ---------- Athens
W. W. Ballard ---------- Experiment
A. R. Brown ---------- Athens
G. W. Burton ---------- Tifton
D. Cantwell ---------- Atlanta
R. L. Carter ---------- Tifton
L. V. Crowder ---------- Experiment
H. G. Cunningham ---------- Atlanta
A. D. Dacus ---------- Athens
J. W. Dobson, Jr. ---------- Blairsville
C. W. Domby ---------- Athens
J. M. Elrod ---------- Experiment
A. A. Fleming ---------- Athens
W. H. Freeman ---------- Tifton
I. Forbes, Jr. ---------- Tifton
F. P. Gardner ---------- Athens
J. E. Giddens ---------- Athens
U. R. Gore ---------- Experiment
L. K. Halls ---------- Tifton
H. B. Harris ---------- Experiment
B. H. Hendrickson ---------- Athens
J. H. Hunter ---------- Albany
H. A. Inglis ---------- Athens
E. James ---------- Experiment
E. V. Komarek ---------- Thomasville
E. S. Lyons ---------- Cairo
J. H. Massey ---------- Experiment
J. T. Miller ---------- Albany
J. H. Miller ---------- Athens
J. E. Moore ---------- Atlanta
J. C. Morcook, Jr. ---------- Atlanta
H. D. Morris ---------- Athens
I. Neas ---------- Tifton
A. A. Nikitin ---------- College Park
M. B. Parker ---------- Blairsville
S. B. Parkmann ---------- Tifton
J. F. Reed ---------- Atlanta
B. P. Robinson ---------- Tifton
O. E. Sell ---------- Experiment
A. J. Singletary ---------- Blakely
T. J. Stafford ---------- Athens
M. Stelly ---------- Athens
R. H. Webster ---------- Experiment
E. C. Westbrook ---------- Athens

IDAHO

G. O. Baker ---------- Moscow
R. Ensign ---------- Aberdeen
H. L. Morton ---------- Moscow
R. M. Naylor ---------- Emmett
W. K. Pope ---------- Moscow
E. N. Poulson ---------- Boise
E. G. Schafer ---------- Pocatello
F. H. Siddoway ---------- St. Anthony
H. Stevens ---------- Aberdeen

ILLINOIS

D. E. Alexander ---------- Urbana
H. J. Bacon ---------- Roseville
L. J. Bartelli ---------- Urbana
F. C. Bauer ---------- Urbana
L. F. Bauman ---------- Urbana
A. L. Bear ---------- Decatur
A. H. Beavers ---------- Urbana
Z. H. Beers ---------- Chicago
E. H. Bitcover ---------- West Chicago

W. R. Boggess ..... Robbs
V. S. Bond ..... Quincy
O. T. Bonnett ..... Urbana
A. H. Bowers ..... Chicago
M. C. Boyle ..... Chicago
R. H. Bray ..... Urbana
M. Brawner ..... Princeton
R. R. Bruce ..... Urbana
A. W. Burger ..... Urbana
L. M. Camp ..... Aurora
R. A. Carrigan ..... Chicago
J. L. Cartter ..... Urbana
R. R. Copper ..... Piper City
E. E. De Turk ..... Decatur
W. T. Dible ..... Chicago
G. H. Doscher ..... Chicago
L. R. Downs ..... Piper City
G. H. Dungan ..... Urbana
E. B. Earley ..... Urbana
C. H. Farnham ..... Urbana
J. B. Fehrenbacher ..... Urbana
K. A. Ford ..... Chicago
L. E. Gard ..... Simpson
H. L. Garrard ..... Homewood
H. L. Garwood ..... Stonington
C. E. Geise ..... Rochelle
F. W. Geise ..... Chicago
R. W. Gerdel ..... Glenview
J. C. Gideon ..... Urbana
J. E. Gieseking ..... Urbana
M. B. Gillis ..... Skokie
R. E. Gish ..... Champaign
A. F. Grandt ..... Farmington
C. L. Gunn ..... DeKalb
L. E. Haley ..... Urbana
S. F. Hanrahan ..... Rochelle
W. Heekendorn ..... Chicago
A. A. Hendrickson ..... Chicago
F. D. Hoblit ..... Atlanta
J. R. Holbert ..... Bloomington
Z. M. Holmes ..... Edelstein
J. E. Hubbard ..... Peoria
J. R. Huey ..... Granville
F. S. Ingersoll ..... Champaign
J. A. Jackobs ..... Urbana
R. I. Jackson ..... Canton
L. M. Jones ..... DeKalb
I. H. Jorgensen ..... Lawrenceville
R. W. Jugenheimer ..... Urbana
E. M. Kitchen ..... East Alton
A. A. Klingebiel ..... Urbana
A. Klute ..... Urbana
T. Kurtz ..... Urbana
A. L. Lang ..... Urbana
R. A. Larkin ..... Peoria
E. R. Leng ..... Urbana
C. M. Linsley ..... Urbana
M. H. Lockwood ..... Chicago
W. H. Lowry ..... Chicago
G. W. Luvisi ..... Chicago
H. F. Massey ..... Skokie
D. L. Maxwell ..... Chicago
G. E. McKibben ..... Glendale
O. S. Meierhenry ..... Chicago
S. W. Melsted ..... Urbana
L. B. Miller ..... Champaign
R. A. Miller ..... Chicago
D. L. Mulvaney ..... Urbana
W. J. Mumm ..... Milford
J. C. Neill ..... Champaign
W. B. Nevens ..... Urbana
G. L. Noble ..... Chicago
L. M. Null ..... Colchester
R. T. Odell ..... Urbana
L. E. Oncken ..... Tuscola
R. D. Osler ..... Urbana
E. J. Pedersen ..... Sycamore
J. W. Pendleton ..... Urbana
J. J. Pierre ..... Champaign
R. R. Poynor ..... Chicago
E. Reeve ..... West Chicago
W. R. Reid ..... Aurora
J. F. Rundquist ..... Butler
D. A. Russel ..... Urbana
M. B. Russell ..... Urbana
G. W. Schmitz ..... Evanston
W. O. Scott ..... Urbana
R. F. Seabury ..... Jacksonville
O. H. Sears ..... Urbana
D. L. Shauer ..... Aurora
E. B. Schultz, Jr. ..... Chicago
E. G. Sieveking ..... Normal
F. W. Slife ..... Urbana
P. R. Smith ..... Oakwood
R. S. Stauffer ..... Urbana
L. Steele ..... Bloomington
F. J. Stevenson ..... Urbana
R. P. Thomas ..... Chicago
J. E. Thompson ..... Chicago
A. U. Thor ..... Urbana
J. S. Titus ..... Urbana
J. L. Trisler ..... Fairmount
T. C. Tucker ..... Urbana
E. H. Tyner ..... Urbana
L. Van Horn ..... Cerro Gordo
M. Vineyard ..... Decatur
D. L. Wallace ..... Mt. Vernon
H. L. Wascher ..... Urbana
S. A. Watson ..... Argo
R. O. Weibel ..... Urbana
A. L. Whiting ..... Urbana
R. E. Williams ..... Champaign
D. C. Wimer ..... Urbana
C. M. Woodworth ..... Urbana
R. S. Yohe ..... Chicago

INDIANA

J. J. Anderson ..... Lafayette
S. A. Barber ..... Lafayette
N. M. Baughman ..... Lafayette
A. R. Bertrand ..... West Lafayette
R. D. Bronson ..... West Lafayette
A. M. Brunson ..... Lafayette
T. M. Bushnell ..... West Lafayette
R. M. Caldwell ..... West Lafayette
J. W. Calland ..... Decatur
P. L. Crane ..... Lafayette
W. H. Daniel ..... Lafayette
R. L. Davis ..... Lafayette
C. Dienhart ..... Kentland
G. H. Enfield ..... West Lafayette
C. L. Ford ..... Roby
L. Ford ..... Butler
L. R. Frederick ..... Lafayette
M. R. Garner ..... Richmond
F. R. Gomes ..... West Lafayette
A. R. Hilst ..... West Lafayette
G. N. Hoffer ..... Lafayette
W. W. Huffine ..... Lafayette
H. A. Jongedyk ..... Lafayette
M. M. Justin ..... West Lafayette
H. Kohnke ..... Lafayette
B. L. Korty ..... Lafayette
H. H. Kramer ..... Lafayette
J. E. Larsen ..... Lafayette
P. F. Low ..... Lafayette
A. R. Marston ..... Tipton
S. R. Miles ..... Lafayette
A. C. Moll ..... Indianapolis
G. D. Mott ..... West Lafayette
L. J. Munzenmaier, Jr. ..... Elkhart
J. E. Newman ..... West Lafayette
A. J. Ohlrogge ..... Lafayette
F. L. Patterson ..... Lafayette
J. B. Peterson ..... Lafayette
F. A. Post ..... Boonville
A. H. Probst ..... West Lafayette
H. W. Reuszer ..... Lafayette
G. L. Richardson ..... Lafayette
D. A. Sander ..... Lafayette
G. D. Scarseth ..... Lafayette
J. F. Schafer ..... Lafayette
J. P. Seaton ..... Lafayette
R. T. Smith ..... West Lafayette
A. E. Spooner ..... West Lafayette
N. L. Stoltenberg ..... West Lafayette
J. L. Strauss ..... Washington
M. R. Teel ..... Lafayette
J. Thorp ..... Richmond
J. F. Trost ..... Lafayette
C. E. Troyer ..... La Fontaine
H. P. Ulrich ..... West Lafayette
W. E. Vandeventer ..... Princeton
N. J. Volk ..... West Lafayette
G. P. Walker ..... West Lafayette
J. L. White ..... Lafayette
E. A. Wildman ..... Richmond
L. K. Wyckoff ..... Valparaiso

IOWA

D. C. Anderson ..... Hampton
M. A. Anderson ..... Ames
S. R. Anderson ..... Ames
R. E. Atkins ..... Ames
R. Baker ..... Johnston
R. Balser ..... Des Moines
W. V. Bartholomew ..... Ames
W. F. Bennett ..... Cedar Rapids
C. A. Black ..... Ames
D. R. Bouldin ..... Ames
L. W. Briggle ..... Ames
R. G. Brown ..... Clarinda
G. M. Browning ..... Ames
W. P. Byrd ..... Ames
M. A. Campbell ..... Coon Rapids
S. J. Chao ..... Clear Lake
S. S. Chase ..... Ames
F. E. Clark ..... Ames
E. G. Crocker ..... Storm Lake
J. H. Curme ..... Ames
C. S. Dorchester ..... Ames
L. C. Dumenil ..... Ames
E. R. Duncan ..... Ames
E. S. Dyas ..... Ames
J. C. Eldridge ..... Ames
D. D. Evans ..... Ames
B. J. Firkins ..... Ames
K. J. Frey ..... Ames
H. A. Fribourg ..... Ames
S. F. Goodsell ..... Des Moines
H. D. Gross ..... Ames
R. B. Gunn ..... Dayton
J. J. Hanway ..... Ames
G. W. Harmon ..... Sioux City
V. B. Hawk ..... Ankeny
A. L. Hooker ..... Ames
M. M. Hoover, Sr. ..... Ames
H. D. Hughes ..... Ames
C. D. Hutchcroft ..... Ames
G. J. Jarvis ..... Ames
G. D. Johnson ..... Des Moines
I. J. Johnson ..... Ames
R. R. Kalton ..... Ames
W. F. Keim ..... Ames
D. Kirkham ..... Ames
R. E. Krenzin ..... Ames
A. Leffler ..... Johnston
J. O. Legg ..... Ames
D. F. Matzinger ..... Alleman
G. McCart ..... Ames
R. J. McCracken ..... Ames
L. McCurdy ..... Fremont
M. J. McNeilly ..... Shenandoah
D. Metcalfe ..... Ames
H. C. Murphy ..... Ames
R. P. Nicholson ..... Ames
D. G. Oberts ..... Vinton
L. C. Ohle ..... Des Moines
L. H. Penny ..... Ames

J. T. Pesek, Jr. ---------- Ames
W. H. Pierre ---------- Ames
R. C. Prill ---------- Ames
F. F. Riecken ---------- Ames
J. L. Robinson ---------- Ames
J. R. Runkles ---------- Ames
W. A. Russell ---------- Ames
G. M. Schafer ---------- Ames
F. W. Schaller ---------- Ames
R. W. Schlick ---------- Shenandoah
L. A. Schneider ---------- Coon Rapids
J. M. Scholl ---------- Ames
G. O. Schwab ---------- Ames
A. D. Scott ---------- Ames
R. H. Shaw ---------- Ames
W. D. Shrader ---------- Ames
S. M. Smith ---------- Sigourney
G. F. Sprague ---------- Ames
G. Stanford ---------- Ames
H. L. Sutton, Jr. ---------- Burlington
D. Swartzendruber ---------- Ames
R. M. Swenson ---------- Ames
W. I. Thomas ---------- Ames
H. Thompson ---------- Ames
L. M. Thompson ---------- Ames
H. R. Thumma ---------- Laurens
R. I. Turner ---------- Hampton
J. R. Webb ---------- Ames
C. R. Weber ---------- Ames
E. M. White ---------- Ames
W. C. White ---------- Ames
S. C. Wiggans ---------- Ames
C. P. Wilsie ---------- Ames

KANSAS

F. W. Albertson ---------- Hays
K. L. Anderson ---------- Manhattan
M. C. Axelton ---------- Meade
L. F. Baker, Jr. ---------- Topeka
O. W. Bidwell ---------- Manhattan
P. L. Brown ---------- Hays
A. J. Casady ---------- Hays
W. S. Chepil ---------- Manhattan
A. L. Clapp ---------- Manhattan
E. A. Cleavinger ---------- Manhattan
L. L. Compton ---------- Manhattan
F. E. Davidson ---------- Mound Valley
C. D. Davis ---------- Manhattan
R. Ellis, Jr. ---------- Manhattan
H. C. Engdahl ---------- Colby
W. L. Fowler ---------- Hays
J. C. Frazier ---------- Manhattan
B. L. Grover ---------- Garden City
R. J. Hanks ---------- Manhattan
E. D. Hansing ---------- Manhattan
J. O. Harris ---------- Manhattan
E. G. Heyne ---------- Manhattan
J. A. Hobbs ---------- Manhattan
W. Inman ---------- Topeka
C. O. Johnston ---------- Manhattan
J. B. Kuska ---------- Colby
H. H. Laude ---------- Manhattan
A. E. Lowe ---------- Garden City
E. L. Mader ---------- Manhattan
J. D. McNeal ---------- Manhattan
W. A. Moore ---------- Hutchinson
H. E. Myers ---------- Manhattan
J. T. Neill ---------- Emporia
R. V. Olson ---------- Manhattan
A. W. Pauli ---------- Manhattan
A. T. Perkins ---------- Manhattan
W. M. Phillips ---------- Hays
R. C. Pickett ---------- Manhattan
W. W. Rasmussen ---------- Manhattan
J. C. Roark ---------- Wichita
W. M. Ross ---------- Hays
J. W. Schmidt ---------- Manhattan
F. W. Smith ---------- Manhattan
L. A. Tatum ---------- Manhattan
R. I. Throckmorton ---------- Manhattan
T. L. Walter ---------- Colby
L. E. Willoughby ---------- Manhattan
V. W. Woestemeyer ---------- Topeka
J. W. Zahnley ---------- Manhattan
A. W. Zingg ---------- Manhattan

KENTUCKY

R. C. Buckner ---------- Lexington
E. N. Fergus ---------- Lexington
B. W. Fortenbery ---------- Lexington
J. F. Freeman ---------- Lexington
J. S. Harrison ---------- Lexington
L. Henson ---------- Lexington
P. E. Karraker ---------- Lexington
D. A. Reid ---------- Lexington
G. Roberts ---------- Lexington
W. A. Seay ---------- Lexington
J. F. Shane ---------- Lexington
W. G. Survant ---------- Lexington
N. L. Taylor ---------- Lexington

LOUISIANA

A. O. Alben ---------- Shreveport
W. H. Anthony ---------- Opelousas
T. J. Arceneaux ---------- Lafayette
I. J. Becnel ---------- New Orleans
R. H. Brupbacher ---------- Baton Rouge
D. S. Byrnside, Jr. ---------- Baton Rouge
C. C. Cain ---------- Lafayette
W. E. Dee ---------- Amite
B. N. Driskell ---------- Baton Rouge
J. P. Gray ---------- Baton Rouge
H. E. Hammar ---------- Shreveport
M. T. Henderson ---------- Baton Rouge
D. M. Johns ---------- Homer
J. E. Jones ---------- Baton Rouge
C. W. McMichael ---------- Houma
R. L. Miller ---------- Baton Rouge
J. Y. Oakes ---------- Bossier City
C. R. Owen ---------- University Station
J. M. Peek ---------- Lafayette
F. A. Peevy ---------- Alexandria
W. J. Peevy ---------- Baton Rouge
F. W. Self ---------- Baton Rouge
E. C. Simon ---------- Baton Rouge
J. P. Stanford ---------- Baton Rouge
H. Stoneburg ---------- Baton Rouge
M. B. Sturgis ---------- Baton Rouge
R. K. Walker ---------- Crowley

MAINE

C. S. Brown ---------- Orono
P. N. Carpenter ---------- Orono
H. J. Murphy ---------- Orono
K. F. Nielsen ---------- Orono
R. A. Struchtemeyer ---------- Orono
L. H. Taylor ---------- Orono
H. W. Trask ---------- Orono
M. F. Trevett ---------- Orono
H. E. Young ---------- Orono

MARYLAND

O. S. Aamodt ---------- Beltsville
J. K. Ableiter ---------- Beltsville
L. T. Alexander ---------- Beltsville
F. E. Allison ---------- Beltsville
M. S. Anderson ---------- Beltsville
W. H. Armiger ---------- Beltsville
M. E. Austin ---------- Beltsville
J. H. Axley ---------- College Park
R. H. Bamberg ---------- Hyattsville
H. D. Barker ---------- Beltsville
J. Bartz ---------- Frederick
R. P. Bates ---------- College Park
B. B. Bayles ---------- Beltsville
B. F. Beacher ---------- Silver Spring
D. F. Beard ---------- Beltsville
D. R. Bianco ---------- Silver Spring
J. M. Blume ---------- Beltsville
G. A. Bourbeau ---------- College Park
J. C. Brown ---------- Beltsville
J. C. Bryant ---------- Bethesda
J. G. Cady ---------- Beltsville
K. G. Clark ---------- Beltsville
E. E. Clayton ---------- Beltsville
F. A. Coffman ---------- Beltsville
J. S. Cole ---------- Silver Spring
D. M. Crooks ---------- Beltsville
W. A. Davidson ---------- Cheverly
L. A. Dean ---------- Beltsville
G. T. Den Hartog ---------- Beltsville
H. R. DeRose ---------- Frederick
R. S. Dyal ---------- Beltsville
T. W. Edminster ---------- Beltsville
R. H. Engle ---------- Bethesda
L. W. Erdman ---------- Beltsville
D. T. Fangemeyer ---------- Baltimore
C. E. Ferguson ---------- Beltsville
W. R. Findley, Jr. ---------- Beltsville
R. J. Fortier ---------- Baltimore
M. Fried ---------- Beltsville
C. S. Garrison ---------- Beltsville
F. V. Grau ---------- College Park
H. Graumann ---------- Beltsville
A. A. Hanson ---------- Beltsville
M. A. Hein ---------- Beltsville
S. B. Hendricks ---------- Silver Spring
P. R. Henson ---------- Beltsville
E. A. Hollowell ---------- Beltsville
J. M. Huffington ---------- Towson
O. J. Hunt ---------- Silver Spring
H. L. Hyland ---------- Silver Spring
K. D. Jacob ---------- Beltsville
M. T. Jenkins ---------- Beltsville
F. R. Johnson ---------- Baltimore
O. J. Kelley ---------- Beltsville
T. Kerr ---------- Beltsville
V. J. Kilmer ---------- Beltsville
H. S. Klosky ---------- Baltimore
J. Kubota ---------- Beltsville
A. O. Kuhn ---------- College Park
R. C. Leffel ---------- College Park
R. L. Lovvorn ---------- Beltsville
W. Z. Mackie ---------- Beltsville
J. H. Martin ---------- Beltsville
D. D. Mason ---------- Beltsville
O. R. Mathews ---------- Beltsville
B. L. Matzek ---------- Beltsville
J. E. McMurtrey, Jr. ---------- Beltsville
R. G. Menzel ---------- Beltsville
A. H. Moseman ---------- Beltsville
O. R. Neal ---------- Frederick
D. C. Nearpass ---------- Beltsville
L. B. Nelson ---------- Beltsville
A. S. Newman ---------- Frederick
A. C. Orvedal ---------- Lanham
F. W. Parker ---------- Beltsville
W. W. Pate ---------- College Park
R. L. Pendleton ---------- Baltimore
J. R. Pomeroy ---------- Baltimore
K. S. Quisenberry ---------- Beltsville
R. F. Reitemeier ---------- Beltsville
S. Rieger ---------- Beltsville
O. C. Rogers ---------- College Park
T. S. Ronningen ---------- College Park
R. G. Rothgeb ---------- College Park
S. C. Salmon ---------- Beltsville
V. Sauchelli ---------- Baltimore
R. E. Shapiro ---------- Beltsville
W. C. Shaw ---------- Beltsville
C. S. Slater ---------- Beltsville
A. M. Smith ---------- Baltimore
H. M. Smith ---------- Hyattsville
A. W. Specht ---------- Brookeville
S. P. Stabler ---------- Spencerville
T. R. Stanton ---------- Hyattsville
R. W. Starostka ---------- Beltsville
J. J. Stilwell, Jr. ---------- Elkton

E. Strickling ..... College Park
V. K. Toole ..... Lanham
R. E. Uhland ..... Beltsville
A. J. Vessel ..... Beltsville
R. E. Wagner ..... Beltsville
W. F. Watkins ..... Chevy Chase
M. G. Weiss ..... Beltsville
C. W. Whittaker ..... Beltsville
G. A. Wiebe ..... Beltsville
H. D. Woofter ..... Frederick

MASSACHUSETTS

J. A. Chucka ..... West Springfield
W. G. Colby ..... Amherst
G. Cornish ..... Amherst
R. W. Donaldson ..... Amherst
M. Drake ..... Amherst
F. A. Filios ..... Amherst
P. S. Mangelsdorf ..... Cambridge
R. T. Martin ..... Cambridge
J. L. Parsons ..... Amherst
H. Plate ..... West Springfield
D. H. Sieling ..... Amherst
J. E. Steckel ..... Amherst
J. Vengris ..... Amherst
F. Verdoorn ..... Waltham
E. K. Walrath ..... West Springfield

MICHIGAN

S. D. Alfred ..... East Lansing
B. L. Allen ..... East Lansing
F. R. Austin ..... Galesburg
H. H. Bailey ..... East Lansing
A. S. Baker ..... East Lansing
G. D. Bedell ..... Rose City
E. J. Benne ..... East Lansing
T. C. Bigger ..... East Lansing
P. Birko ..... Detroit
H. W. Bockstahler ..... East Lansing
G. Bouyoucos ..... East Lansing
L. J. Braamse ..... East Lansing
W. S. Brammell, Jr. ..... East Lansing
H. M. Brown ..... East Lansing
R. L. Caralus ..... East Lansing
W. Cargo ..... Marquette
B. R. Churchill ..... East Lansing
R. L. Cook ..... East Lansing
J. F. Davis ..... East Lansing
S. T. Dexter ..... East Lansing
M. DeYoung ..... Grand Rapids
W. E. Dickison ..... Sault Ste. Marie
R. E. Dils ..... East Lansing
E. E. Down ..... East Lansing
C. Engberg ..... East Lansing
M. H. Erdmann ..... East Lansing
A. E. Erickson ..... East Lansing
M. G. Frakes ..... Saginaw
W. S. Fraser ..... Calumet
J. R. Guttay ..... Lansing
C. M. Harrison ..... East Lansing
S. C. Hildebrand ..... East Lansing
H. W. Hough ..... East Lansing
K. Lawton ..... East Lansing
E. D. Longnecker ..... East Lansing
R. E. Lucas ..... East Lansing
L. J. McKenzie ..... East Lansing
J. E. McKittrick ..... Benton Harbor
C. E. Millar ..... East Lansing
M. J. Murray ..... Kalamazoo
L. V. Nelson ..... East Lansing
A. G. Norman ..... Ann Arbor
K. T. Payne ..... East Lansing
H. R. Pettigrove ..... East Lansing
S. Pollack ..... East Lansing
J. A. Porter ..... East Lansing
P. A. Reeve ..... Saginaw
L. S. Robertson ..... East Lansing
E. C. Rossman ..... East Lansing
I. F. Schneider ..... East Lansing
S. H. Spurr ..... Ann Arbor
L. H. Stolzy ..... East Lansing
M. B. Tesar ..... East Lansing
L. M. Turk ..... East Lansing
A. J. Watson ..... South Haven
H. L. Weber ..... Traverse City
A. G. Weidemann ..... East Lansing
E. P. Whiteside ..... East Lansing
B. C. Williams ..... East Lansing
H. Wittels ..... East Lansing

MINNESOTA

H. Abraham ..... Minneapolis
F. J. Alway ..... St. Paul
E. R. Ausemus ..... St. Paul
J. D. Barnard ..... Le Sueur
R. N. Bieter ..... Mankato
R. E. Bothun ..... St. Paul
W. W. Brookins ..... Minneapolis
P. M. Burson ..... St. Paul
A. C. Caldwell ..... St. Paul
R. E. Clark ..... Le Sueur
J. O. Culbertson ..... St. Paul
R. S. Dunham ..... St. Paul
L. J. Elling ..... St. Paul
R. S. Farnham ..... St. Paul
D. G. Fletcher ..... Minneapolis
S. Folsom ..... Minneapolis
H. I. Fossen ..... Fergus Falls
B. Haapala ..... Dassel
H. K. Hayes ..... Minneapolis
H. E. Jones ..... St. Paul
M. A. Kiess ..... Collegeville
J. W. Lambert ..... St. Paul
W. C. Landgren ..... Willmar
F. A. Loeffel ..... St. Paul
J. H. Longwell, Jr. ..... St. Paul
R. N. McCaull ..... Minneapolis
W. P. MacDonald ..... Minneapolis
J. M. MacGregor ..... St. Paul
P. R. McMiller ..... St. Paul
W. M. Myers ..... St. Paul
O. Newlin ..... St. Paul
I. J. Nygard ..... St. Paul
G. Ogata ..... Minneapolis
L. E. Orth ..... St. Paul
E. L. Pinnell ..... Waseca
G. Rauenhorst ..... Olivia
R. G. Robinson ..... St. Paul
C. O. Rost ..... St. Paul
O. E. Rud ..... St. Paul
P. D. Sanders ..... Redwood Falls
A. R. Schmid ..... St. Paul
E. L. Schmidt ..... Minneapolis
R. E. Schobert ..... Mankato
O. C. Soine ..... Crookston
H. L. Thomas ..... St. Paul
J. R. Watson, Jr. ..... Minneapolis
A. F. Wiese ..... St. Paul

MISSISSIPPI

W. B. Andrews ..... State College
C. E. Bardsley, Jr. ..... State College
H. W. Bennett ..... State College
D. H. Bowman ..... Stoneville
W. M. Broadfoot ..... Vicksburg
H. D. Bunch ..... State College
C. A. Carlson ..... Vicksburg
D. W. Chisholm ..... Jackson
W. A. Cole ..... Belzoni
O. H. Coleman ..... Meridian
W. J. Drapala ..... State College
R. C. Eckhardt ..... State College
W. B. Ennis, Jr. ..... State College
H. Evans ..... Shaw
W. L. Giles ..... Stoneville
G. D. Green ..... State College
E. E. Hartwig ..... Stoneville
P. G. Hogg ..... Stoneville
C. D. Hoover ..... State College
U. S. Jones, Jr. ..... State College
H. V. Jordan ..... State College
W. E. Keenan ..... Greenwood
W. E. Knight ..... State College
J. D. Lancaster ..... State College
C. W. Manning ..... Stoneville
S. Marchbanks ..... State College
W. S. McGuire ..... State College
J. R. Meyer ..... Stoneville
E. B. Minton ..... Stoneville
L. C. Murphree ..... Decatur
L. E. Nelson ..... State College
J. F. O'Kelly ..... State College
I. E. Stokes ..... Meridian
H. F. Wallace ..... Canton
D. G. Wells ..... State College
L. N. Wise ..... State College

MISSOURI

W. A. Albrecht ..... Columbia
E. Anderson ..... St. Louis
B. H. Beard ..... Columbia
H. D. Black ..... Columbia
E. M. Brown ..... Columbia
J. Chrisman ..... Kansas City
J. C. Engibous ..... St. Louis
T. Fisher ..... Columbia
P. W. Fletcher ..... Columbia
W. S. Gillam ..... Kansas City
E. R. Graham ..... Columbia
W. C. Hansel ..... Carrollton
R. E. Hess ..... Bethany
D. O. Howe ..... Columbia
A. Klemme ..... Columbia
D. L. Klingman ..... Columbia
C. L. Koehler ..... Columbia
H. H. Krusekopf ..... Columbia
C. E. Marshall ..... Columbia
M. F. Miller ..... Columbia
P. Onstot ..... Joplin
J. E. Patterson ..... Kansas City
J. M. Poehlman ..... Columbia
E. R. Sears ..... Columbia
V. L. Sheldon ..... Columbia
D. D. Smith ..... Columbia
G. E. Smith ..... Columbia
G. V. Taylor ..... Kansas City
D. M. Whitt ..... Columbia
C. L. Wilson ..... Kirkwood
C. M. Woodruff ..... Columbia
M. S. Zuber ..... Columbia

MONTANA

T. S. Aasheim ..... Huntley
J. A. Asleson ..... Bozeman
L. O. Baker ..... Havre
D. E. Baldridge ..... Moccasin
M. A. Bell ..... Bozeman
W. C. Bourne ..... Bozeman
S. N. Brooks ..... Huntley
R. F. Eslick ..... Bozeman
E. E. Frahm ..... Bozeman
E. R. Hehn ..... Bozeman
J. C. Hide ..... Bozeman
R. Jones ..... Anaconda
J. L. Krall ..... Moccasin
W. E. Larson ..... Bozeman
F. H. McNeal ..... Bozeman
E. A. Nieschmidt ..... Billings
R. D. Peace ..... Havre
F. C. Petr ..... Bozeman
A. H. Post ..... Bozeman
A. F. Shaw ..... Bozeman
V. R. Stewart ..... Creston
R. E. Stitt ..... Bozeman
R. F. Walz ..... Bozeman
R. M. Williams ..... Moccasin

NEBRASKA

A. R. Aandahl — Lincoln
R. Allmaras — Mitchell
R. D. Brigham — Aurora
L. Chesnin — Lincoln
W. Collins, Jr. — Lincoln
E. C. Conard — Lincoln
E. H. Doll — Lincoln
A. F. Dreier — Lincoln
F. L. Duley — Lincoln
R. L. Fox — Lincoln
E. F. Frolik — Lincoln
C. O. Gardner — Lincoln
T. H. Goodding — Lincoln
D. G. Hanway — Lincoln
V. A. Johnson — Lincoln
W. M. Johnson — Lincoln
W. R. Kehr — Lincoln
F. D. Keim — Lincoln
T. A. Kiesselbach — Lincoln
F. E. Koehler — Lincoln
R. O. Lewis — Lincoln
J. H. Lonnquist — Lincoln
R. P. Matelski — Lincoln
A. P. Mazurak — Lincoln
T. M. McCalla — Lincoln
D. P. McGill — Lincoln
C. A. Mogen — Lincoln
L. C. Newell — Lincoln
R. A. Olson — Lincoln
K. Peter — Omaha
C. R. Porter — Lincoln
L. P. Reitz — Lincoln
H. F. Rhoades — Lincoln
P. H. Stewart — Omaha
A. D. Stoesz — Lincoln
G. T. Webster — Lincoln
O. J. Webster — Lincoln
V. A. Welch — Fremont
V. H. Welch — Fremont
M. D. Weldon — Lincoln
B. H. Williams — Lincoln
J. H. Williams, Jr. — Lincoln
G. F. Worker, Jr. — Lincoln
C. H. Yien — Lincoln

NEVADA

L. E. Dunn — Reno
E. H. Jensen — Reno
M. K. Porter — Reno
W. C. Robocker — Reno
O. F. Smith — Reno
V. E. Spencer — Reno

NEW HAMPSHIRE

R. L. Donahue — Durham
G. M. Dunn — Durham
L. J. Higgins — Durham
L. T. Kardos — Durham
W. H. Lyford — Durham
G. R. Moore — Dover

NEW JERSEY

G. H. Ahlgren — New Brunswick
R. J. Aldrich — New Brunswick
F. R. Anspach — Woodbury Heights
F. App — Bridgeton
W. R. Battle — New Brunswick
J. E. Baylor — New Brunswick
F. E. Bear — New Brunswick
G. R. Blake — New Brunswick
R. A. Briggs — New Brunswick
G. D. Brill — Freehold
J. W. Collier — New Brunswick
R. E. Engel — New Brunswick
N. A. Ferrant, Jr. — Yardville
W. J. Hanna — New Brunswick
J. B. Hester — Riverton
J. S. Joffe — New Brunswick
W. H. Kelly — New Brunswick
W. F. Meggitt — New Brunswick
W. A. Mitcheltree — New Brunswick
C. H. Moran — Riverton
H. P. Newton — Montclair
H. C. Nikola — New Brunswick
W. J. Powers — Mintola
E. R. Purvis — New Brunswick
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R. S. Snell — New Brunswick
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R. L. Starkey — New Brunswick
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S. J. Toth — New Brunswick
J. A. Vomocil — New Brunswick
R. C. Wakefield — New Brunswick
W. W. Washko — New Brunswick
O. W. Willcox — Ridgewood
B. Wolf — Bridgeton
W. E. Zimmerman — Bloomfield

NEW MEXICO

J. S. Cahoon — Silver City
F. O. Case — Albuquerque
C. W. Chang — State College
C. H. Diebold — Albuquerque
H. E. Dregne — State College
M. D. Finkner — State College
C. H. Hsi — Clovis
R. W. Leamer — State College
R. W. Livers — Clovis
J. C. Overpeck — State College
W. P. Sappenfield — State College
G. Staten — State College
G. N. Stroman — State College

NEW YORK

S. R. Aldrich — Ithaca
S. S. Atwood — Ithaca
M. V. Bailey — New York
H. S. Bannister — East Aurora
A. J. Bauer — Ithaca
K. C. Beeson — Ithaca
J. W. Borland — Massappequa, Long Island
D. Boynton — Ithaca
R. Bradfield — Ithaca
N. C. Brady — Ithaca
C. S. Brandt — Ithaca
H. C. Brewer — New York
F. E. Broadbent — Ithaca
H. O. Buckman — Ithaca
F. J. Carlisle, Jr. — Ithaca
B. E. Clark — Geneva
M. G. Cline — Ithaca
N. J. Curtis — Worcester
J. E. Dawson — Ithaca
W. D. Enzie — Albion
H. L. Everett — Ithaca
R. Feuer — Ithaca
G. R. Free — Ithaca
W. L. Garman — Ithaca
H. B. Hartwig — Ithaca
S. B. Haskell — Middletown
R. D. Henson — Buffalo
A. E. Hiltbold — Ithaca
A. W. Hofer — Geneva
J. T. Hood — Ithaca
W. D. Hunnicutt — New York
H. A. Huston — Kew Gardens
N. F. Jensen — Ithaca
A. A. Johnson — Ithaca
W. K. Kennedy — Ithaca
E. G. Knox — Ithaca
C. F. Konzak — Upton, Long Island
K. Kopf — Niagara Falls
W. E. Lafkin — White Plains
D. J. Lathwell — Ithaca
O. C. Leetun — New York
E. W. Leland — Ithaca
H. H. Love — Ithaca
C. C. Lowe — Ithaca
R. D. Miller — Ithaca
T. E. Milliman — Ithaca
R. P. Murphy — Ithaca
R. B. Musgrave — Ithaca
H. B. Neville — Farmingdale
M. Peech — Ithaca
E. E. Pfeiffer — Spring Valley
H. L. Porter, Jr. — Elmira
E. W. Rynas — Goldens Bridge
L. Saltonstall, Jr. — Ithaca
N. Sanchez D. — Ithaca
C. B. Sayre — Geneva
G. H. Serviss — Ithaca
N. J. Shaulis — Geneva
J. R. Sheffield — New York
W. R. Singleton — Upton, Long Island
J. H. Sprague, Jr. — New York
E. L. Stone, Jr. — Ithaca
E. Taschdjian — Brooklyn
E. R. Townsend — Buffalo
A. R. Twombly — Pleasant Valley
J. F. Underwood — Ithaca
E. Van Alstine — Ithaca
M. T. Vittum — Geneva
L. C. Walker — Syracuse
D. P. White — Syracuse
R. G. Wiggans — Ithaca
E. L. Worthen — Brooktondale
P. J. Zwerman — Ithaca

NORTH CAROLINA

J. L. Allison — Raleigh
T. J. Army — Raleigh
R. L. Bernard — Raleigh
H. J. Bragg — Washington
D. S. Chamblee — Raleigh
W. V. Chandler — Raleigh
E. R. Collins — Raleigh
W. E. Colwell — Raleigh
W. A. Cope — Raleigh
T. L. Copley — Raleigh
R. Cummings — Raleigh
S. H. Dobson — Raleigh
J. F. Doggett — Raleigh
P. N. Drolsom — Oxford
G. H. Earle, Jr. — Raleigh
W. H. Eyster — Plymouth
J. W. Fitts — Raleigh
L. A. Forrest — Raleigh
F. N. Goforth — Wilson
E. F. Goldston — Wallace
W. C. Gregory — Raleigh
N. S. Hall — Raleigh
C. H. Hanson — Raleigh
D. G. Harris — Raleigh
P. H. Harvey — Raleigh
M. E. Harward — Raleigh
T. B. Hutcheson, Jr. — Raleigh
W. A. Jackson — Raleigh
H. W. Johnson — Raleigh
G. L. Jones — Raleigh
G. C. Klingman — Raleigh
W. D. Lee — Raleigh
J. F. Lutz — Raleigh
T. E. Maki — Raleigh
T. J. Mann — Raleigh
C. McAuliffe — Raleigh
S. B. McCaleb — Raleigh
A. C. McClung — Raleigh
A. Mehlich — Raleigh
G. K. Middleton — Raleigh
E. V. Miller — Raleigh
P. A. Miller — Raleigh
R. P. Moore — Raleigh
J. B. Murphy — Greensboro

W. L. Nelson ---------- Raleigh
P. H. Reid ---------- Raleigh
J. A. Rigney ---------- Raleigh
H. F. Robinson ---------- Raleigh
T. J. Sheets ---------- Raleigh
W. O. Shepherd ---------- Asheville
A. D. Stuart ---------- Laurinburg
D. L. Thompson ---------- Raleigh
R. P. Upchurch ---------- Raleigh
C. H. M. van Bavel ---------- Raleigh
W. G. Woltz ---------- Raleigh
W. W. Woodhouse, Jr. ---------- Raleigh
E. T. York, Jr. ---------- Raleigh

NORTH DAKOTA

J. S. Allen ---------- Mandan
L. L. Anderson ---------- Fargo
D. L. Bannister ---------- Rugby
J. F. Carter ---------- Fargo
G. N. Geiszler ---------- Minot
H. J. Gorz ---------- Fargo
D. L. Grunes ---------- Mandan
H. J. Haas ---------- Mandan
H. R. Haise ---------- Mandan
R. M. Heermann ---------- Fargo
K. L. Lebsock ---------- Fargo
V. G. Link ---------- Mandan
J. E. McClelland ---------- Fargo
E. B. Norum ---------- Fargo
H. W. Omodt ---------- Jamestown
G. A. Rogler ---------- Mandan
S. H. Shih ---------- Mandan
W. W. Sisler ---------- Fargo
G. S. Smith ---------- Fargo
T. E. Stoa ---------- Fargo
H. L. Walster ---------- Fargo
W. C. Whitman ---------- Fargo
W. Wiidakas ---------- Fargo
R. A. Young ---------- Fargo
J. C. Zubriski ---------- Fargo

OHIO

M. A. Bachtell ---------- Wooster
E. E. Barnes ---------- Wooster
A. Baxter ---------- Columbus
R. H. Blackmore ---------- Worthington
H. L. Borst ---------- Wooster
L. Brewster ---------- Swanton
E. O. Burt ---------- Columbus
D. R. Butler ---------- Columbus
W. D. Case ---------- Dayton
W. S. Colvin ---------- Ironton
H. L. Cook ---------- Columbus
H. P. Cords ---------- Columbus
R. S. Davidson ---------- Columbus
R. R. Davis ---------- Wooster
F. R. Dreibelbis ---------- Coshocton
V. C. Finkner ---------- Columbus
D. T. Friday ---------- Worthington
E. F. Geyer ---------- Grove City
G. R. Gist ---------- Columbus
E. S. Halley ---------- Columbus
R. E. Hay, Jr. ---------- Columbus
J. L. Haynes ---------- Wooster
R. M. Hiatt ---------- Wilmington
N. Holowaychuk ---------- Columbus
W. C. Huff ---------- Columbus
R. D. Ilnicki ---------- Columbus
R. L. Jeffers ---------- Columbus
E. Jones ---------- Columbus
G. Keith ---------- Huron
L. L. Knudsen ---------- Wooster
E. R. Kuck ---------- New Knoxville
C. A. Lamb ---------- Wooster
W. P. Martin ---------- Columbus
J. S. McCoy ---------- Cincinnati
H. J. Mederski ---------- Wooster
R. L. Meeker ---------- Columbus
M. K. Miller ---------- Cincinnati
H. H. Morse ---------- Columbus
J. L. Mortensen ---------- Columbus
G. J. Noggle ---------- Xenia
C. T. Ozaki ---------- Wooster
J. B. Park ---------- Urbana
R. D. Peel ---------- Wooster
P. F. Pratt ---------- Columbus
E. P. Reed ---------- Columbus
A. S. Richardson ---------- Cincinnati
E. L. Robinson ---------- Columbus
M. B. Root ---------- Celina
W. J. Russell ---------- Columbus
L. C. Saboe ---------- Columbus
P. W. Santelmann ---------- Columbus
S. Schwartz ---------- Columbus
J. A. Slipher ---------- Columbus
J. M. Stackhouse ---------- Columbus
G. H. Springfield ---------- Wooster
D. W. Tanger ---------- Bellefontaine
A. D. Taylor ---------- Toledo
G. S. Taylor ---------- Columbus
L. E. Thatcher ---------- Wooster
V. A. Tiedjens ---------- Marion
H. H. Tucker ---------- Columbus
G. W. Volk ---------- Columbus
E. I. Walters ---------- Cleveland
C. J. Willard ---------- Columbus
R. Yost ---------- Thornville

OKLAHOMA

A. D. Ayers ---------- Tulsa
B. M. Beard ---------- Oklahoma City
O. H. Brensing ---------- Stillwater
J. S. Brooks ---------- Stillwater
R. A. Chessmore ---------- Ardmore
H. A. Daniel ---------- Guthrie
J. Dreessen ---------- Stillwater
H. V. Eck ---------- Stillwater
F. Gray ---------- Stillwater
J. M. Green ---------- Stillwater
J. R. Harlan ---------- Stillwater
H. J. Harper ---------- Ardmore
B. R. Jackson ---------- Stillwater
R. J. Jones ---------- Stillwater
W. R. Kneebone ---------- Woodward
J. Q. Lynd ---------- Stillwater
R. MacVicar ---------- Stillwater
R. S. Matlock ---------- Stillwater
E. H. McIlvain ---------- Woodward
H. F. Murphy ---------- Stillwater
R. M. Oswalt ---------- Stillwater
W. Parkey ---------- Stillwater
D. H. Reno ---------- Tulsa
A. M. Schlehuber ---------- Stillwater
L. F. Thompson ---------- Ardmore
H. C. Young, Jr. ---------- Stillwater

OREGON

A. C. Anderson ---------- Roseburg
L. E. Andrew ---------- Klamath Falls
W. W. Austin ---------- Portland
K. Baur ---------- Portland
H. B. Cheney ---------- Corvallis
O. C. Compton ---------- Corvallis
C. S. Cooper ---------- Burns
J. R. Cowan ---------- Corvallis
H. E. Cushman ---------- Corvallis
E. W. Dull ---------- Gresham
D. W. Fishler ---------- Corvallis
W. H. Foote ---------- Corvallis
R. E. Fore ---------- Corvallis
A. L. Hafenrichter ---------- Portland
W. E. Hall ---------- Moro
D. D. Hill ---------- Corvallis
H. B. Howell ---------- Astoria
A. S. Hunter ---------- Corvallis
E. R. Jackman ---------- Corvallis
T. L. Jackson ---------- Corvallis
K. R. Keller ---------- Corvallis
P. Lemmon ---------- Portland
L. D. MacKellar ---------- Portland
A. W. Marsh ---------- Corvallis
J. W. Miller ---------- Pendleton
W. B. Neuburg ---------- Hillsboro
R. A. Pendleton ---------- Corvallis
C. R. Rohde ---------- Pendleton
H. A. Schoth ---------- Corvallis
H. L. Schudel ---------- Corvallis
G. K. Smith ---------- Prineville
R. E. Stephenson ---------- Albany
H. E. Tower ---------- Portland
V. Valassis ---------- Corvallis
H. M. Waddoups ---------- Pendleton
L. E. Warner ---------- Pendleton
E. P. Winters ---------- Cove
L. N. Wright ---------- Imbler
C. T. Youngberg ---------- Corvallis

PENNSYLVANIA

H. R. Adams ---------- Upper Darby
H. R. Albrecht ---------- State College
R. B. Alderfer ---------- State College
R. H. Beatty ---------- Ambler
N. Bethlahmy ---------- Bethlehem
C. R. Blackmon ---------- Farm School
A. Brokans ---------- Harrisburg
C. S. Bryner ---------- State College
H. L. Carnahan ---------- State College
J. S. Cobb ---------- State College
A. T. Corey ---------- Allison Park
T. Eastwood ---------- Berwick
J. L. Edge ---------- State College
M. E. Farnham ---------- W. Conshohocken
H. R. Fortmann ---------- State College
K. V. Goodman ---------- Coudersport
D. W. Gordon ---------- Doylestown
C. K. Hallowell ---------- Philadelphia
J. F. Haseman ---------- West Chester
H. W. Higbee ---------- State College
F. J. Holben ---------- State College
L. L. Huber ---------- State College
L. L. Hug ---------- Landisville
C. D. Jeffries ---------- State College
J. P. Jones ---------- Upper Darby
V. J. Keenan ---------- Philadelphia
C. W. Klopp ---------- Bernville
J. Lamb, Jr. ---------- Lansdowne
W. Leach ---------- Scranton
G. F. Loughry ---------- State College
T. Mascaro ---------- West Point
G. K. McCutcheon ---------- New Holland
M. C. McJunkin ---------- State College
F. G. Merkle ---------- State College
J. P. Miller ---------- State College
H. B. Musser ---------- State College
A. L. Patrick ---------- Upper Darby
R. P. Pennington ---------- State College
F. S. Prince ---------- Upper Darby
S. M. Raleigh ---------- State College
A. C. Richer ---------- State College
R. R. Robinson ---------- State College
D. P. Satchell ---------- State College
E. Schneider ---------- Lancaster
H. L. Schwanz ---------- Philadelphia
B. L. Seem ---------- Emmaus
V. G. Sprague ---------- State College
V. H. Unger ---------- Philadelphia
J. Valentine ---------- Ardmore
J. B. Washko ---------- State College
R. D. Wennblom ---------- Philadelphia
H. K. Wilson ---------- State College
E. D. Witman ---------- Pittsburgh

RHODE ISLAND

R. S. Bell ---------- Kingston
J. A. DeFrance ---------- Kingston
T. E. Odland ---------- Kingston
M. Salomon ---------- Kingston
J. B. Smith ---------- Kingston
I. H. Stuckey ---------- Kingston
H. W. Zussman ---------- Providence

SOUTH CAROLINA

W. B. Albert — Clemson
R. Y. Bailey — Spartanburg
O. W. Beale — Clemson
J. F. Chaplin — Florence
G. H. Collings — Clemson
H. P. Cooper — Clemson
O. L. Copeland, Jr. — Union
G. L. Fuller — Spartanburg
R. E. Gettys — Hartsville
S. J. Haden — Hartsville
M. D. Hoover — Union
J. H. Hoyert — Blackville
C. M. Jones — Clemson
M. W. Lowry — Spartanburg
A. Manwiller — Florence
T. C. Maurer — Spartanburg
F. L. McNatt — Clemson
L. J. Metz — Union
R. J. Metzger — Clemson
J. W. Neely — Hartsville
W. R. Paden — Clemson
T. C. Peele — Clemson
M. M. Phillippe — Clemson
A. B. Prince — Clemson
B. M. Ritter — Clemson
C. H. Rogers — Hartsville
W. B. Rogers — Blackville
R. D. Shipman — Charleston
J. C. Slone — Spartanburg
E. H. Stewart — Clemson
P. Tabor — Spartanburg
H. A. Woodle — Clemson

SOUTH DAKOTA

M. W. Adams — Brookings
B. Baird — Newell
B. L. Brage — Brookings
R. E. Campbell — Brookings
P. L. Carson — Brookings
L. A. Derscheid — Brookings
E. L. Erickson — Brookings
L. O. Fine — Brookings
C. Franzke — Brookings
J. E. Grafius — Brookings
G. D. Johnson — Brookings
R. C. Kinch — Brookings
D. E. Kratochvil — College Station
L. L. Ladd — Brookings
U. J. Norgaard — Brookings
L. F. Puhr — Brookings
J. G. Ross — Brookings
D. B. Shank — Brookings
A. O. Syverud — College Station
F. C. Westin — Brookings
W. W. Worzella — Brookings

TENNESSEE

C. B. Breinig — McMinnville
F. S. Chance — Knoxville
M. J. Edwards — Knoxville
H. E. Heggestad — Greenville
W. J. Huddleston — Cookeville
W. C. Lassetter — Memphis
J. K. Leasure — Knoxville
L. Lett — Memphis
W. S. Ligon — Knoxville
O. H. Long — Knoxville
W. H. MacIntire — Knoxville
J. W. Moon — Knoxville
B. C. Nichols — Greenville
R. Q. Parks — Memphis
W. L. Parks — Knoxville
G. H. Robinson — Knoxville
K. B. Sanders — Knoxville
L. F. Seatz — Knoxville
W. M. Shaw — Knoxville
D. M. Simpson — Knoxville
L. N. Skold — Knoxville
M. F. Spaulding — Nashville
A. J. Sterges — Knoxville
S. L. Tisdale — Knoxville
M. E. Weeks — Knoxville
S. H. Winterberg — Knoxville
E. Winters — Knoxville

TEXAS

G. H. Abel — Lubbock
J. E. Adams — College Station
I. M. Atkins — Denton
C. Ayers — Lubbock
A. A. Baltensperger — Denton
H. M. Beachel — Beaumont
L. S. Bird — Bryan
M. E. Bloodworth — Bryan
J. E. Bower — Denton
L. E. Brooks — Iowa Park
E. Burnett — Spur
R. L. Cheaney — Beaumont
P. D. Christensen — Ysleta
C. W. Clift — Hawkins
L. C. Coffey — College Station
W. B. Coke — College Station
E. D. Cook — Temple
W. R. Cowley — Weslaco
G. S. Cox — Nacogdoches
A. W. Crain — Houston
L. E. Crane — Beaumont
D. I. Dudley — Denton
M. H. Ferguson — College Station
A. A. Fetooh — College Station
C. E. Fisher — Spur
H. D. Foth — College Station
F. A. Frank — Austin
J. F. Fudge — College Station
M. C. Futrell — College Station
H. W. Gausman — Weslaco
C. J. Gerrard — College Station
C. L. Godfrey — College Station
C. M. Gregg — San Marcas
L. J. Gundy — Renner
H. L. Hackerott — Renner
H. H. Hadley — College Station
H. E. Hampton — College Station
C. Harvey — Canyon
E. C. Holt — College Station
C. S. Hoveland — Winter Haven
C. C. Jaynes — Lubbock
P. R. Johnson — Tyler
J. R. Johnston — College Station
D. L. Jones — Lubbock
L. C. Kapp — College Station
R. E. Karper — Lubbock
M. L. Kinman — College Station
N. W. Kramer — Lubbock
C. H. H. ter Kuile — Renner
G. W. Kunze — College Station
G. H. Kuykendall — Littlefield
B. C. Langley — Stephenville
W. D. Laws — Renner
E. R. Lemon — College Station
R. D. Lewis — College Station
H. D. Loden — Plainview
T. C. Longnecker — Renner
P. J. Lyerly — Ysleta
C. M. Lyman — College Station
J. H. McDonald — Navasota
E. S. McFadden — College Station
A. Nakornthap — College Station
D. D. Neher — Kingsville
W. M. Nixon — Ft. Worth
M. J. Norris, Jr. — McGregor
J. B. Page — College Station
R. E. Patterson — College Station
K. B. Porter — Amarillo
R. C. Potts — College Station
J. R. Quinby — Chillicothe
H. E. Rea — College Station
R. G. Reeves — College Station
E. B. Reynolds — College Station
T. R. Richmond — College Station
J. S. Rogers — College Station
G. B. Schulz — McAllen
R. L. Schwartz — Abilene
K. Seymour — College Station
B. L. Sims — Weslaco
J. A. Smith — Dallas
J. C. Smith — Angleton
R. M. Smith — Temple
M. C. Sparr, Jr. — Follett
H. B. Sprague — Dallas
R. H. Stansel — Alvin
J. C. Stephens — Chillicothe
E. H. Templin — College Station
M. K. Thornton — College Station
R. M. Tripp — Dallas
W. O. Trogdon — Wichita Falls
I. P. Trotter — College Station
D. L. Van Horn — Plainview
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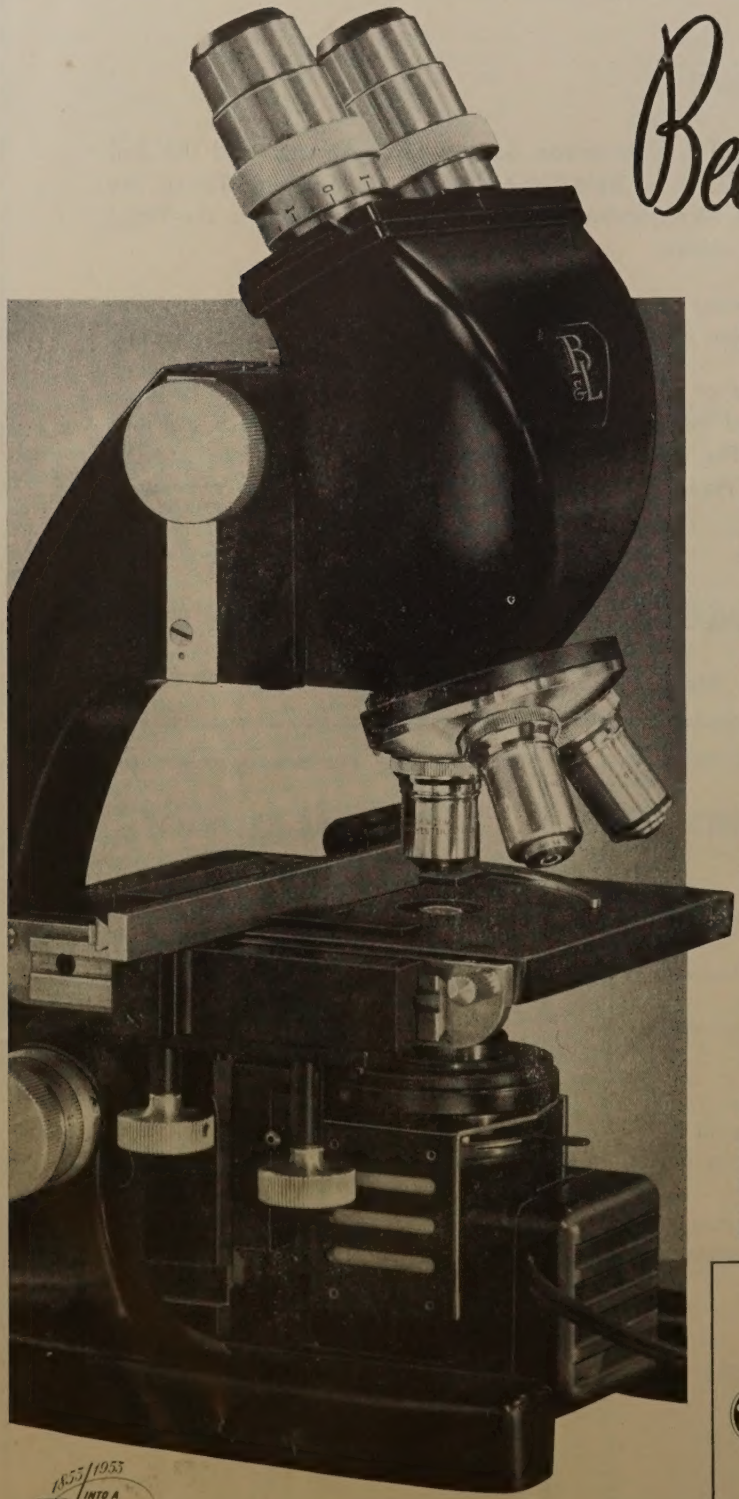

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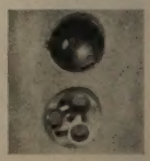

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